GEOMORPHOLOGICAL, GEOECOLOGICAL, GEOARCHEOLOGICAL, AND SURFICIAL MAPPING STUDY OF McGREGOR GUIDED MISSILE RANGE, FORT BLISS, NEW MEXICO

VOLUME I

by
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for
U.S. Army Corps of Engineers
Fort Worth District
and
Fort Bliss Military Reservation

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The scope of the study is reflected in its title: to provide a general geomorphologic, soil, geoarcheologic, and surficial mapping study of the McGregor Range. The purpose is to produce an explanatory model of Quaternary landscape evolution. The study is also intended to provide baseline information on the geology, water resources, landforms, and soils of the McGregor Range, plus explore new and old concepts and background information as a collective intellectual resource base for future environmental assessments, for resource management, and for mitigation and compliance considerations. In one sense this is geoarcheological study, but in another it is a geoecological study, one that focuses on the dynamic processes that have operated to produce the modern landscape of McGregor Range and environs.

This study began in July 1995 during a visit to Fort Bliss by the author in the company of Dr. GalerBurgett, R. Joe Brandon, and Kelly Poché of Fort Bliss Directorate of Environment (DOE). The visit was arranged by Dr. Jim Zeidler of United States Army Construction Engineering Research Laboratories (USACERL), Champaign, Illinois, and included a three-day connaissance of parts of the McGregor Range. Detailed fieldwork began in September 1995 and continued intermittently into July 1996.

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VOLUME I

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Fieldwork and other research have been greatly aided in one way or another by various individuals, most notably by archeologists Galen Burgett, Kelly Poché, R. Joe Brandon, Kelly Fischer, Shane Offett, and Ken Faunce, ecologist Kevin von Finger, and botanist Rafael Corral-Diaz, all of Fort Bliss DOE; by Ned Finney, geologist and Vice President of Jobe Quarries, El Paso and White Sands; by Curtis Monger and Brenda Buck, pedologists at NMSU; by Raymond Mauldin, archeologist at the University of Texas at El Paso (UTEP); by archeologist Jeff Leach of Centro de Investigaciones Arqeologicas, El Paso; by Steve Hall, University of Texas at Austin; by ranchers Pearl Lewis and Pop Snow of Otero Mesa, Charlie Lee of Hat Ranch on Otero Mesa, Pete Atkins of Helms Ranch on Otero Mesa, Jimmy Bowen of Triple T Bowen Ranch in Chaparrel, Rob Cox of San Augustine Ranch at Organ, and Bill McNew, III, and Philip and Roy Holcomb of Alamogordo; by Orogrande residents Al Tengelitsch, Bill Ward, Earl Johnson and Pat Johnson; by USACERL scientists Jim Zeidler, Scott Tweddale, Bill Jackson, and Caitlin Hamer of Champaign; by Nancy R. Wizner, Chief Ranger of White Sands National Monument; by Art Metcalf, biologist at UTEP; by Scotty McNeish of Andover, MA; and by backhoe operator Eligio Aragon (Alley Cat) of Peralta, NM. DOE personnel also arranged for occasional storage of coring and other equipment and supplies during periods of work recess, a courtesy that was appreciated.

Resource and materials acquisitions have been greatly aided by Geo-Marine, Inc., of Plano, Texas; by the Fort Bliss DOE, El Paso, Texas, and USACERL, Champaign, Illinois, personnel noted above; by Tim Murphy, Bruce Call, Theresa Henley, and Lorraine Salas of BLM, Las Cruces, New Mexico; by Rick Huff of USGS, Las Cruces; by Joe Bailey of Otero-Lincoln Counties Landfill, Alamogordo, New Mexico; by Bill Happel of EROS Data Center, Minot, North Dakota; by Wayne Wendland and Ken Kunkle of the Illinois State Water Survey, Urbana (Kunkle was former State Climatologist for New Mexico, and before that meteorologist at White Sands Missile Range); by personnel of the Otero County Engineers and Soil Conservation Service offices in Alamogordo, and by Hiram Muse and others in Civil Engineering at Holloman Air Force Base, Alamogordo.

Laboratory work has been either aided and/or executed by Linda Scott Cummings of Paleolabs, Inc., of Golden, Colorado (pollen); by Stephen Hall, Geography Department, University of Texas, Austin (pollen); by Ken Robertson and other naturalists of the Illinois State Natural History Survey, Urbana, Illinois (plant identifications); by Jack Liu, Wang Hong, and Rich Cahill of the Illinois State Geological Survey, Urbana, Illinois (^{14}C work, geochemical analyses); by David Hammer of the University of Missouri, Columbia, Missouri (soil-sediment physical and chemical characterizations); and by Larry Abbott of the University of Illinois, Urbana-Champaign (UIUC), Urbana, Illinois (^{14}C pretreatments).

The soil descriptions were examined by Nelson Rolong, soil scientist of the Fort Bliss soil survey staff under the supervision of Dal G. Sprankle, Fort Bliss Soil Survey Project Leader, USDA-NRCS, Tucson, Arizona. Most of the soil classifications were suggested by Rolong based on his examination of the descriptions.

Cartography and map work have been greatly aided by Petra Jelinek and Kevin Robertson, respectively, of the Anthropology and the Plant Biology departments, UIUC, Illinois. I especially thank Diana Johnson of the World Heritage Museum, University of Illinois, Urbana, Illinois, (also my wife) for serving as a very able, conscientious and lovable field assistant, for the excellent graphics in this report, for a conscientious job of editing, and for innumerable other aspects of support, including a great effort in cartography.

Finally, I thank personnel at Geo-Marine, Inc., of Plano, Texas; personnel at Fort Bliss, Texas, and with the U.S. Army; and taxpayers for various levels of financial support for this project. Keith Landreth and Galen Burgett are owed a debt of gratitude for helping formulate the research design, for aiding in various phases of project execution, for encouragement, and for showing confidence and extreme patience in bringing this project to a successful and useful conclusion.

CHAPTER 1
INTRODUCTION

Following discussions with Fort Bliss personnel in the summer of 1995, geomorphological, soil, and geoarcheological investigations were begun by the investigator and colleagues at the McGregor Guided Missile Range (McGregor Range) portion of the Fort Bliss Military Reservation in Otero County, southcentral New Mexico (Figures 1 and 2). The McGregor Range is expansive, covering approximately 1,075 square miles (2,790 km^2), with elevations ranging between 4,000 ft (1,219 m) in the Tularosa Basin to greater than 7,000 ft (2,134 m) in the southern Sacramento Mountains. A wide variety of microclimates, landforms, soils, animals, and plants are present, and intriguing legacies of human occupations lie scattered across the reservation.

SCOPE, PURPOSE, AND SCHEDULE OF WORK

The scope of the study is reflected in its title: to provide a general geomorphologic, soil, geoarcheologic, and surficial mapping study of the McGregor Range. The purpose is to produce an explanatory model of Quaternary landscape evolution. The study is also intended to provide baseline information on the geology, water resources, landforms, and soils of the McGregor Range, plus explore new and old concepts and background information as a collective intellectual resource base for future environmental assessments, for resource management, and for mitigation and compliance considerations. In one sense this is a geoarcheological study, but in another it is a geoecological study, one that focuses on the dynamic processes that have operated to produce the modern landscape of McGregor Range and environs.

This study began in July 1995 during a visit to Fort Bliss by the author in the company of Dr. Galen Burgett, R. Joe Brandon, and Kelly Poché of Fort Bliss Directorate of Environment (DOE). The visit was arranged by Dr. Jim Zeidler of United States Army Construction Engineering Research Laboratories (USACERL), Champaign, Illinois, and included a three-day reconnaissance of parts of the McGregor Range. Detailed fieldwork began in September 1995 and continued intermittently into July 1996. The fieldwork phase, during which time several progress reports were produced, was scheduled as follows:

1995
September 28-October 3
November 16-27
December 11-23
December 28-31

1996
January 1-8
March 7-18
May 10-22, 25-31
June 1-15
July 12-30

Figure 1. Satellite photomosaic of the Tularosa Basin and surrounding region, New Mexico. Photomosaic consists of multiple images of Landsat 2 and 3 taken October 1977 and October 1978 (modified from New Mexico Highway Geologic Map, NMGS 1982).

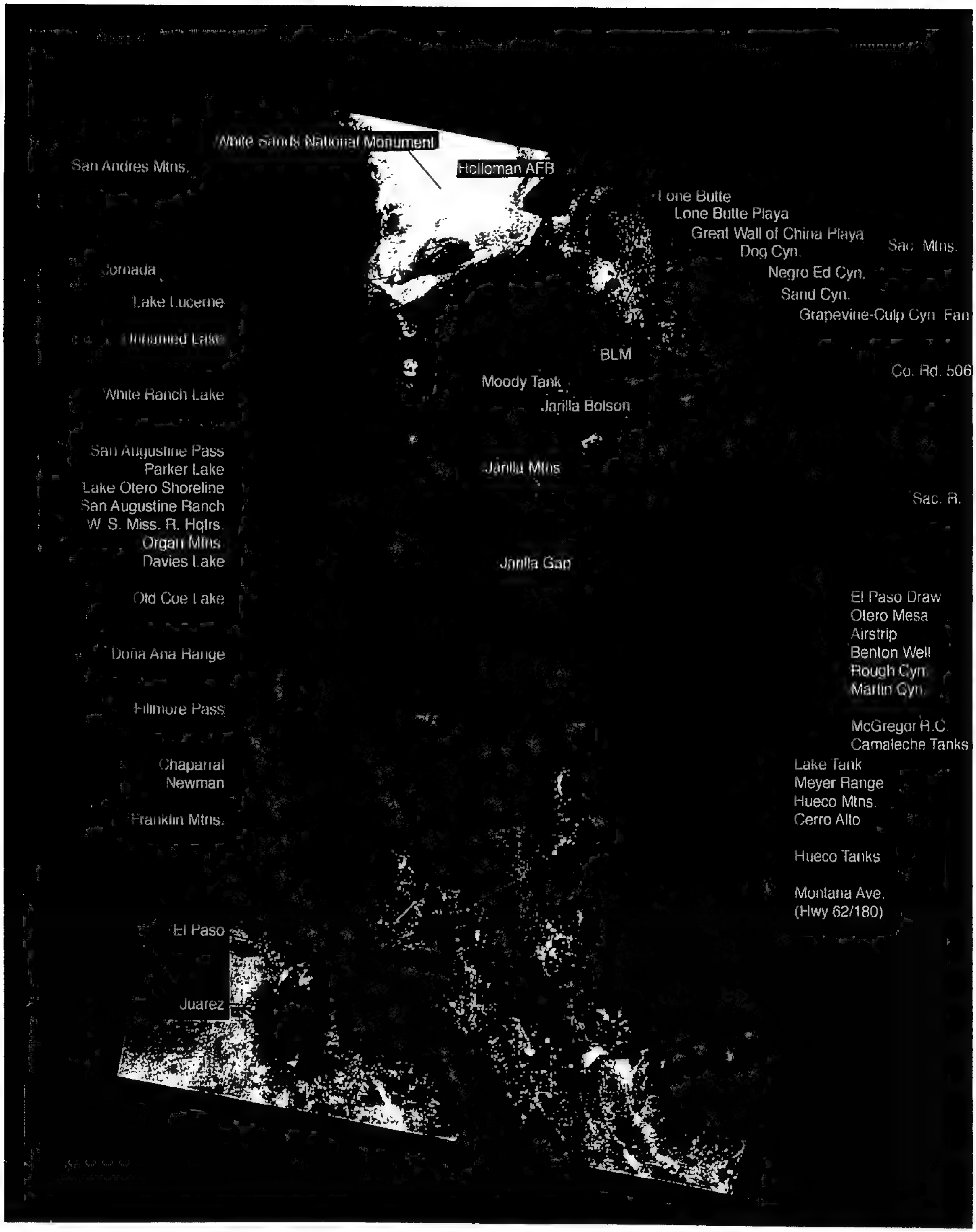


Figure 2. Landsat 4 photo of November 9, 1994, of the southern Tularosa Basin and environs. Fort Bliss, which includes McGregor Range, is outlined in red; place names and important features discussed in text are identified. Image supplied by USACERL, Champaign, Il.

Initial library work revealed that while some useful geomorphic, soils, and geoarcheologic work had been done on the McGregor Range prior to 1995, more baseline information was needed to fully evaluate the prehistoric and Quaternary paleoenvironmental record of this large area. Consequently the investigative work that DOE personnel initiated in 1995 offered a golden opportunity to enlighten our understanding of the prehistoric and paleoecologic heritage of this key crossroads of southwestern North America. Hopefully this report is an important step in accomplishing this task.

STRUCTURE OF REPORT

This study consists of two volumes. Volume I is the textual report, and Volume II contains 28 topographic-geomorphic 7.5-minute quadrangle maps of the McGregor Range (1:24,000 scale). An index map of these 28 maps is presented in both Volume I and Volume II.

Volume I is structured as follows. Chapter 1 is an introduction, which includes the scope, purpose, and schedule of work, and the structure of the report. Chapter 2, the research goals and methods employed, consists of explanation of geographic names used (toponymy), maps, philosophical and conceptual approaches, and caveats. Chapter 3 presents the geoecological overview and assessment of McGregor Range, beginning with an environmental overview, then assessing its physiography, bedrock geology, geologic structure and faults, hydrology and water resources, and concluding with the geomorphology and soils. Geoarcheologic implications of this multithematic assessment are developed here and there. Chapter 4 presents the conclusions and recommendations. Following the body of the report is a list of references and library materials consulted, as well as a brief glossary of terms and concepts used, plus some new place names. The five appendices at the end of Volume I contain information on radiocarbon and pollen data, climatological data, two appendices on soils and sediments in the McGregor area, and a literature review of prior studies in the area.

Volume II is the maps volume. It contains an index map and 28 topographic-geomorphic maps. It also contains a narrative on how the maps were produced, the rationale behind the mapping units, and a summary of the mapping strategy. The narrative is a recapitulation of some of the text in Volume I and was done in order to allow Volume II to stand alone in the event that only the maps volume is used in the field.

CHAPTER 2
RESEARCH GOALS AND METHODS

This study is based on field and laboratory work, map study, air photo analyses, and analyses of library materials and other documents. In addition, various oral and written communications were conducted with archeologists, ecologists, geologists, geomorphologists, soil scientists, and ranchers who have experience in the McGregor Range, Fort Bliss, and west Texas-southern New Mexico areas.

FIELDWORK

Fieldwork was conducted variously on foot, by autos, trucks, and by helicopter (an overview flight). It was augmented by use of various maps of different scales; by various color, black-and-white, and infrared air photos at different scales; by natural exposures; by a trailer-mounted Giddings hydraulic coring rig; and by backhoe. As indicated, reconnaissance fieldwork began in July 1995, and substantive fieldwork began the following September and continued intermittently through July 1996. Much of the fieldwork was aided by field assistant D. N. Johnson, but other individuals aided from time to time. At the contractor's suggestion, in June 1996 Dr. Steve Hall, palynologist-geologist from the University of Texas, Austin, spent several days in the field with the contractor and sampled several playa backhoe pits for pollen, which ultimately proved fortuitous (explicated below).

LABORATORY WORK

Laboratory analyses, with the resulting data presented as Table 1 and in tables in the following chapters and utilized in soil-sediment descriptions in Appendix D, were done in the following laboratories:

1. Sediment-Soils Laboratories, Department of Soil and Atmospheric Sciences, University of Missouri, Columbia, Missouri; POC, Dr. Dave Hammer.
   - •Analyses done: part. size, water-saltpH, org. C, cations-sum-acidity-Al-CECsum-CEC(NH4OAc) meq/100g, %BSsum-BSCEC-7.
   - •Procedures: Those outlined in the January 1996 Natural Resources Conservation Service manual titled *Soil Survey Investigations Report No. 42.*
   - •Samples analyzed: Soil and sediment samples from backhoe pits, Giddings cores, preexistent military pits, and natural and other exposures. Results are in tables are cited later in this report.

Table 1
Radiocarbon (^{14}C) Ages, McGregor Guided Missile Range, Ft. Bliss, NM

Site name/#/ Material Dated	Depth (cm)or level	Lab/#	^{13}C (‰)	Corrected age(rYBP) [1]	Acid pre-treatment [2]
BLM Borrow Pit (site 6) BLM-1, *Salsola kali* L., Russian thistle	base of coppice dune	ISGS 3344	-13.99	113.4±0.6% (late 1950s)	yes
BLM-2b, MRT- SOM [3]	2Ak hor. of Unit 2	ISGS 3382	-19.3	670±90	yes
BLM-3, Caliche (inorganic carb.)	3Bkm hor. of Unit 3	ISGS 3348	-3.9	11,710±110	yes
Escondida Tank Road ESC-1, MRT-SOM	0-20 of buried soil	ISGS 3375	-18.4	790±70	yes
Old Coe Lake Coe-1, MRT-SOM	0-20 of buried soil	ISGS 3377	-21.0	200±70	yes
E. Montana Ave. Jobe sand quarry JSQ-1, MRT-SOM	400-420 of dune pile	ISGS 3387	-21.2	210±70	yes
Vertisol Playa (site 38) Vertisol-1, snail(Planorbid) shells	playa surface	ISGS 3388	-8.4	118.6±0.6% modern, AD 1985-1995	no
Lake Tank Playa (site 34) McGregor-1, pollen, AMS	100-110 of playa	Beta 95521	-20.3	2,730±60	yes
McGregor-2, pollen, AMS	180-190 of playa	Beta 95522	-24.4	5,280±60	yes
Snail Playa Snail Playa-1, Planorbid shells	playa surface	ISGS 3389	-1.6	790±80	no
Dust Pit (site 40) Kangaroo rat dung, 40A, inorg. fraction 40B, org. fraction	60-70 cm of soil pit	ISGS 3524 ISGS 3525	-19.8 -2.5	9,200±70 1,080±110	no yes

1 Radiocarbon years before present (before 1950); age corrected for the effects of isotopic fractionation (Taylor 1987).
2 For SOM, sample is boiled in 2N HCl for one hour as pretreatment to remove inorganic carbon ($CaCO_3$, $CaMgCO_3$). For thin-shelled snails, sample is quick dipped in cold 2N HCl to remove possible thin, nonapparent inorganic carbon film. For pollen, sample is washed in 2N HCl as part of pollen isolation and concentration procedure.
3 Mean Residency Time (MRT) of Soil Organic Matter (SOM).

2. Soil and Sediment Laboratory, Rm 337, Davenport Hall, Geography Department, UIUC, Urbana, Illinois 61801; POC, Mr. Larry Abbott and the contractor.
   - Analyses done: Organic matter pretreated and concentrated, and snail shells pretreated, for conventional $^{14}C/^{13}C$ analyses; descriptions of soil-sediment cores.
   - Samples analyzed: For conventional ^{14}C analyses, all soil organic matter (SOM) indicated later in this report; for sediment-soil descriptions, cores from Bassett Lake and the Escondida site.

3. Illinois State Geological Survey, 615 E. Peabody Drive, Urbana, Illinois 61801; POC, Mr. Jack Liu.
   - Analyses done: $^{14}C/^{13}C$ determinations (13 total).
   - Procedures: Standard $^{14}C/^{13}C$ procedures.
   - Samples analyzed: All organic materials are indicated later in this report.

4. Beta Analytic Inc., 4985 SW 74 Court, Miami, Florida 33155; POC, Mr. Darden G. Hood.
   - Analyses done: AMS (accelerator) $^{14}C/^{13}C$ determinations.
   - Samples analyzed: Pollen grains from Lake Tank (indicated later in this report).

SOIL GEOMORPHOLOGY AND GEOECOLOGY

Soil geomorphology is an approach to explaining Earth surface processes and interpreting landscapes that melds the principles of *geomorphology*, the study of landforms, and *pedology*, the study of soils (Follmer and Johnson 1983; Johnson and Rockwell 1982). Because soil is the epidermis of landforms, it can be said that landforms and soils are genetically one. It is due only to historic accident that the traditions of the two disciplines developed separately. In this study the division is not rigidly recognized but is blurred.

Geoecology is an even more integrated approach (Huggett 1995) that considers all processes that coact to produce complex landscapes like McGregor, of which we humans are a part. The philosophy here is that to understand fully how landscapes evolve—so we can better manage them—we must understand the complex biological, chemical, and physical processes that produced them, including human impacts. This requires a careful multidisciplinary approach that assesses and integrates all of the 'ologies' of the landscape (archeology, geology, ecology, hydrology, etc.). Such is the charge of geoecology.

Soil geomorphological and geoecological analyses normally consist of field and laboratory components, the results of which are combined with other resources to interpret the landscape. One important aspect of the 'geo' side of the field component is to describe soils and sediments visually in pits and other exposures, or from cores, by means of a soil profile description. A soil profile description uses notations for defining horizons (A, Bt, C, etc.) plus certain conventions of descriptions. The notations and conventions have evolved under the guidance of soil scientists, and in this country it has been principally the domain of the Soil Conservation Service (now Natural Resources Conservation Service), a branch of the U.S. Department of Agriculture, and cooperative soil science and agronomy departments in universities and colleges. Their collective mission has been to classify, map, and conserve *surface* soils. But as indicated, conceptual problems arise when the notations and conventions established for surface soils are applied to buried soils, especially buried soil-alluvial complexes that have slowly aggraded and upbuilt through time. Such sequences bear a range of weak to strong pedogenic overprints wherein stratification may be partially preserved or destroyed, and earlier pedogenic signatures may be blurred. Such imprints often impede the ability of geomorphologists, pedologists, and paleopedologists to accurately interpret the record. The problems are fundamental and are addressed in Axioms 6-8 (in Philosophy and Conceptual Approach) and in the Caveats sections of this Introduction.

The general soil geomorphological and geoecological approaches employed here encompass several subapproaches that emphasize process. These processes are the soil evolution, biomantle, dynamic pedogenesis, and dynamic denudation approaches formulated by the author and colleagues (Johnson 1990, 1993; Johnson et al. 1990; Johnson and Watson-Stegner 1983).

SEDIMENT-SOIL DESCRIPTIONS

The sediment-soil descriptions in this report, together with the ^{14}C and laboratory analytic data, provide basic information on which important details of McGregor landscape interpretations rest. Two kinds of

descriptions were produced: abbreviated and expanded. Abbreviated descriptions list horizons, horizon depths, and limited information on most horizons. Expanded descriptions provide much more detail, including the Remarks section that concludes each. Unless specifically identified as abbreviated, the descriptions in this report are expanded. All are in Appendix D.

At the top of each description is information on surface soil classification, the location (and for some, geographic coordinates), the landform, the parent material, slope, the elevation, the surface character, vegetation, who described and who sampled the profile, and what kind of exposure was used for describing and sampling (e.g., backhoe pit, core, etc.). The surface soil classifications were based on soil information and maps in the *Soil Survey of Otero County* (Derr 1981). The descriptions were checked by soil scientists in the Natural Resources Conservation Survey Office, 3003 N. Central Ave., Suite 800, Phoenix, Arizona (Mr. Phil Camp, POC). Some locations and elevations were taken from satellite-linked Magellan GPS units, but were abandoned, and most then extrapolated from USGS 7.5' topographic maps.

PROFILE SCHEMATICS

Humans respond strongly and favorably to visual imagery and, when time is short, favor them over written text. Images convey instant information and context, whereas reading takes time, plus one must conjure an image based strictly on the reading, which may or may not be correct. To maximize communication about a subject, both images and written text must be integrated, and profile schematics aid in this task.

A profile schematic is a graphic representation of the written sediment-soil description. The latter, while an important and essential repository of observations and measurement, often is tedious to read. Profile schematics, on the other hand, in addition to conveying immediate information about a site, can highlight notable aspects of geology, sedimentology, soil horizons, paleosols, stratigraphic data, and other information about the site. Profile schematics can also simplify the complexities of a section as observed in the field and as documented in the sediment-soil descriptions. Profile schematics complement the descriptions in this report insofar as they are based on the descriptions. For this report they were computer-generated using Adobe Illustrator software.

PHOTOS AND PHOTO-PLATE FIGURES

There is also truth to the statement that a photograph is worth a thousand words. Images in general have worth, but photographs have special worth. This is true in all human endeavors, including science. Words and images, like photos, quintessentially augment one another in conveying messages, exacting concepts, and in otherwise explaining complex relationships. The photos in this study do no less, and, as a consequence, this report is liberally endowed with photo-plates presented as figures. Photo-plates are a collection of photos in a figure that convey a common point that is articulated in the figure caption and text. To enable the photo-plate figures to stand alone for users who focus more on visuals than on text, the captions are more explanatory and longer than is normally found in most captions. In other words, if someone scans the photo-plate figures and their captions without reading the text, the central message is still conveyed, though in abbreviated fashion. For this reason the photo-plate figures are considered an essential part of this study.

MAPS

As indicated, 28 geomorphic-topographic maps were produced for this report and are in Volume II. The basemaps used were U.S. Geological Survey (USGS) 7.5-minute quadrangle maps at 1:24,000 scale. Their names are given on the index map (Figure 3).

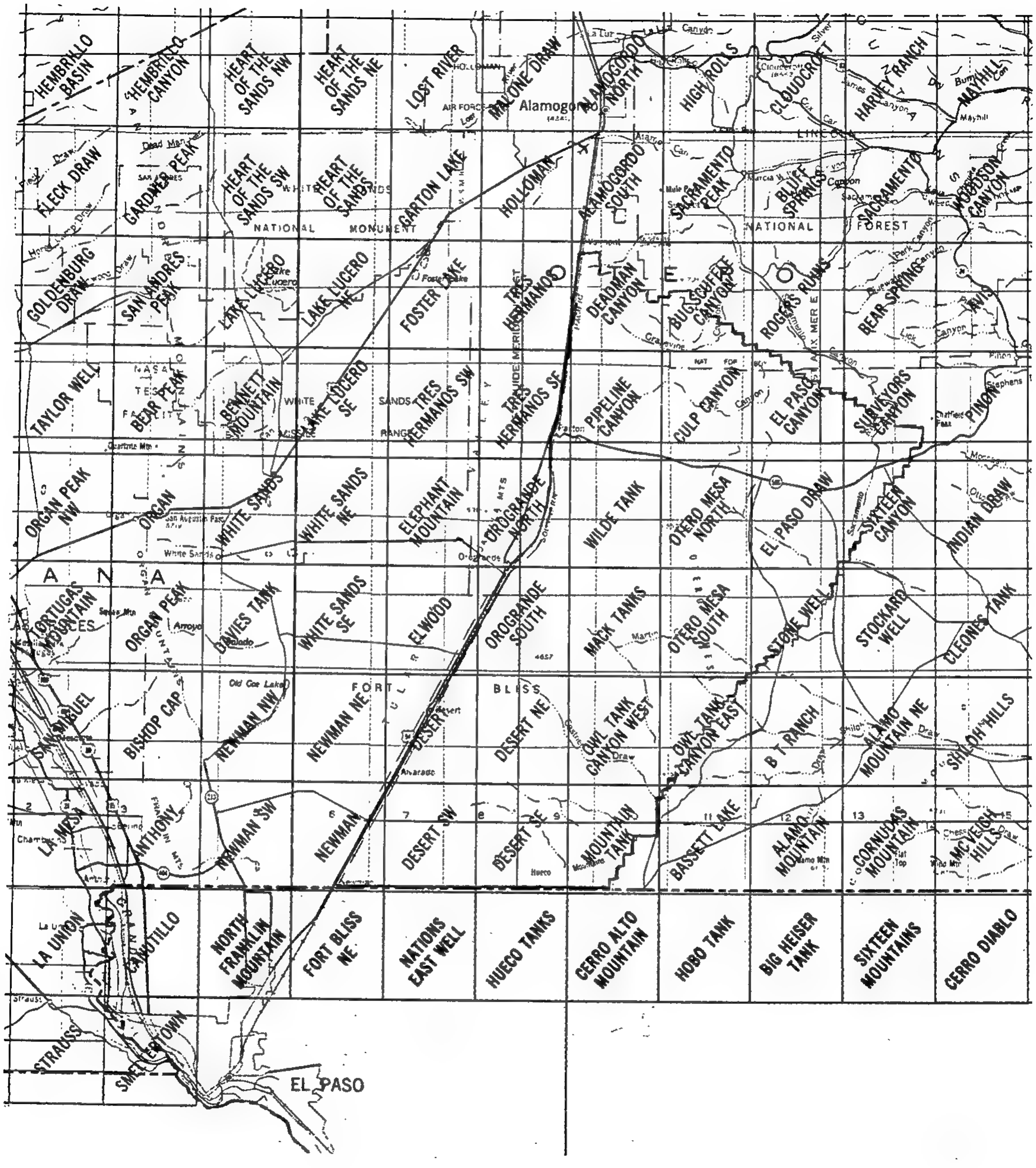


Figure 3. Index map for the 7.5 minute geomorphic-topographic (quadrangle) maps produced for this report.

In the early stages of this project, consideration was given to age-assessing and mapping McGregor Range sediments and surfaces using the Desert Project as a model. That highly respected study, which encompassed an enormous concentration of effort and talent, was conducted in and around the Organ Mountains over many years by L. Gile, J. Hawley, R. Grossman, and their colleagues (Gile et al. 1981; Hawley 1975b). The plan for the present project was to correlate McGregor soils and surfaces to those of the Desert Project, as Monger had done in his recent study of the Fort Bliss Maneuver Areas (Monger 1993). After fieldwork and mapping commenced, however, it gradually became clear that such a strategy required some rethinking, that it might be worth adopting a different strategy for several reasons. One reason is that far more time and resources would be needed for soil-geomorphic work, age-dating surfaces, and ground-truthing maps to enable useful correlations to the Desert Project than was available for the McGregor Range project. In terms of a continuous theater of mapping, the McGregor Range is even larger than the Desert Project theater of study, and that study absorbed many years' work and impressive federal and state resources involving many people and support staff. Further, the Desert Project area was selected for study because the sediments are derived from both carbonate and noncarbonate rocks, especially the latter, whereas McGregor sediments are almost exclusively carbonate derived (Camp Rice fluvial facies excepted, and some alluvium from the Jarilla Mountains). Hence the two areas are not exactly comparable. Paleargids, for example, are common in the Desert Project area, but not on McGregor pediments and uplands (they are present in certain basinal contexts; Derr 1981; Khresat 1993). Also, biotic disturbance vectors, particularly rodents and badgers, commonly reset caliche clocks on McGregor, which complicates using soil development—mainly calcic horizon development—as an age indicator. Further, the philosophical underpinnings of the Natural Resources Conservation Service, U.S. Department of Agriculture (NRCS, USDA), soil geomorphic work is the five-factors approach (cf., Simonson 1997), and, while time-honored and viable as a framework, it is fundamentally different from the unified soil geomorphic-geoecologic process approach employed here. It is a fact of science that different frameworks yield different views and different results. Applying the Desert Project model to McGregor would mean locking most aspects of the mapping and soil-geomorphic work into an existing structured framework—regardless of that framework's justifiably exalted status—that could limit intellectual and interpretive flexibility. Reference and comparison was, nevertheless, readily made to the Desert Project throughout this study, though not necessarily through emulation of emphasis and procedure. Since in the first instance this is a soil geomorphic, geoecologic, and geoarcheologic assessment and mapping study, it was deemed important to produce maps and mapping units that would be both simple and reasonably accurate, employ simple language, and at the same time be optimally useful to a wide field of specialists in resource allocation, management, planning, and mitigation. The mapping strategy and units adopted below hopefully fulfill these user-friendly goals.

The landform mapping units used in this report are as follows:

Landform/Material	Mapping Unit	Landform/Material	Mapping Unit
Alluvium (recent)	A1	Dune Pile	DP
Alluvium (relict)	A2	Dune Sheet	DS
Alluvium (older relict)	A3	Dune Sheet, Coppiced	DSC
Bedrock	B	Dune Sheet, Gypsiferous	DSG
Bolson Floor Complex	---	Fault	---
Camp Rice (Rio Grande) Sediments	CR	Pediment	P
Dune, Local	DL	Playa	Pl
		Playa Lunette	PlL

The first element of any mapping complex on the topographic-geomorphic maps in this report is the most common surface geomorphic element observed in that unit. For example, in the mapping unit DSC/P/A1-A2, coppice dunes formed on sheet sand are most common, but shallow pediments that are overlain by alluvial pedisediment in which weak to moderately strong soils have formed also occur within the complex. This mapping unit would apply along bedrock outliers that front the Tularosa Basin where coppiced dune sheets have migrated up onto pediment slopes of the bedrock outliers. A mapping unit designated A1 means that only recent alluvium is present at the surface.

The reader should know that these mapping units are placed on the maps as best judgements established by air photos, contour maps, orthophotomaps, and necessarily limited ground truthing. By their very nature, most mapping boundaries are informed estimates or inferred approximations of what is actually there. Centers of mapping units have the highest accuracies, boundaries least (hopefully *all* are accurate). Such are the problems that attend efforts to delimit spatially arrayed and genetically graded natural phenomena on maps.

Finally, another, more detailed section on maps introduces Volume II. That section describes the technical aspects of how the maps were made, why USGS 7.5-minute maps were chosen as basemaps, and other map issues. It also recapitulates the philosophy presented above in the event that some users take only Volume II with them into the field.

TOPONYMY AND GEOGRAPHIC NAMES

One difficulty in working on the McGregor Range and communicating about it with others is the dearth of place names, or toponymy, for landscape features. Preexisting names identify some former ranches, homesteads, most tanks, railroad sidings/watering sites, and a few streams. But many features, in particular, specific landforms, lack them. Without toponymy, i.e., names, for individual playas, ridges, valleys, streams, bolsons, depressions, and other features, communication becomes difficult and slow. Discussion about places and sites reduces to much verbiage and map shuffling punctuated by arm waving. To simplify, many landscape features were named in this report and augment existing toponymies of the literature and maps. Old and new names are referred to throughout the text, figures, tables, sediment-soil descriptions and are on the 28 geomorphic-topographic maps produced for this report (see Figure 2).

THE FIVE NATURAL ZONES OF MCGREGOR RANGE

The McGregor Range has five geoecological natural zones (Figure 4):

- The *Jarilla Bolson Zone*: encompasses the northwest part of McGregor, including the normal en echelon-faulted fans below Sacramento Mountain escarpment, specifically the Negro Ed-Grapevine-Culp Canyon fan complex, also including the Jarilla Mountains the Jarilla Bolson, and the Jarilla Gap.

- The *Tularosa Basin Zone*: encompasses the southwestern part of McGregor Range, including the portion underlain by ancient Rio Grande (Camp Rice) fluvial sediments, and the toeslopes of fans that onlap onto it from the east.

- The *Broken Escarpment-Hueco Mountains Zone*: encompasses the area between the Sacramento Mountains-Otero Mesa on the east and the Tularosa Basin on the west, ranging from Negro Ed Canyon on the north to and including the Hueco Mountains on the south. It includes the broken ground between the escarpment and the Tularosa Basin floor, including the Hueco Bedrock Finger, a limestone bedrock outlier on the south side of the Jarilla Gap.

- The *Otero Mesa Zone:* encompasses the mesa tablelands east of the Otero Escarpment, ranging from the Hueco Mountains on the south to the foothills of the Sacramento Mountains on the north.

- The *Sacramento Mountains Zone*: encompasses the southern part of the Sacramento Mountains.

Each is called a natural zone because each has a mix of genetically related landforms, soils, vegetation, and environmental processes and conditions that impart general geoecological identities.

Figure 4. The five geoecological natural zones of McGregor Guided Missile Range, New Mexico.

PHILOSOPHY AND CONCEPTUAL APPROACH

The soil geomorphic, geoecologic, and archeologic interpretations of studies like this invariably reflect a process of observations filtered through assumptions, conditions, concepts, models, and theories. These were partly outlined above in the methodology chapter under the subsection titled Soil Geomorphology and Geoecology. The overall soil geomorphic-geoecologic approach used in this report to explain the landscape evolution of McGregor is a unified dynamic process model termed dynamic denudation that the author and colleagues have been formulating and refining for some years (Johnson 1989, 1990, 1993a, 1993b; Johnson and Balek 1991; Johnson and Watson-Stegner 1987, 1990; Johnson et al. 1987, 1990; Wood and Johnson 1978). The general model is expanded here to include processes that operate in the Chihuahuan desert environment of the McGregor Range. Certain aspects of the philosophy and general truths behind the approach are reflected in the first eight geoecological axioms presented below. The other geoecological axioms are general truths that have emerged from the McGregor Range research reported here. Axioms, as used here, are general truths that are confirmed through repeated and consistent observations. The approach in this report is also based on the concept of process vector analysis, explained below.

Axiom 1: *All elements of a landscape dynamically interact with each other and coevolve with time.* Rocks, slopes, exposure, soils, early and late humans, other animals, plants, other life forms, weather, climate, fire, soil, water, air, earthquakes, volcanoes, and so on all interact and coevolve with time. They are a dynamically integrated whole, and any <u>one</u> of them can cause or contribute to environmental change. More traditional approaches place a high—sometimes exclusive—emphasis on climate as the *sine qua non* of environmental change, that climate determines the basic change and/or stability of vegetation, with cascading effects that then ripple through the system. While numerous studies have shown, as does intuition, that climate is indeed a key variable in setting the general environmental stage, Axiom 1 encourages a more holistic, realistic and environmentally flexible approach—that change of *any* element of the environment can trigger changes that cascade through the system. Certainly the drastic environmental effects wrought by humans and their grazing animals in recent historic time on the McGregor Range confirm this axiom.

Axiom 2: *Soil is the skin of landforms and thus an integral part of them.* Soil is indeed the 'skin' of landforms, just a much as our skin is an integral part of our bodies. It was only through unfortunate historic accident that the study of soil, *pedology*, and that of landforms, *geomorphology*, came to follow separate pathways and develop separate traditions (theory, language, approaches). In this report soils and landforms are considered as one, although conventions followed in the separate traditions of each sometimes make this approach difficult.

Axiom 3: *Environmental processes on Earth, as they impact landforms and soils, are driven by biological, chemical, and/or physical agents.* The point of this axiom is that inasmuch as two of these agents, the chemical and physical ones, operate throughout the universe, the fundamental uniqueness of Earth must be due to all *three* agents, especially biological ones. Expressed differently, because Earth *is* dramatically and fundamentally different from all other celestial bodies, biological agents must be largely responsible for the big difference. Now, most geomorphologic and some pedologic investigations have traditionally tended to emphasize chemical and physical agents as prime factors in landscape evolution, with the role of iota often de-emphasized, or even omitted. While acknowledging that chemical and physical agents are indeed important, conferring the same importance to biological agents allows for more robust, realistic, and flexible environmental interpretive options. Further, it is probable, and here assumed, that most chemical and physical agents on Earth are biologically mediated, and have been for 3-4 billions of years. It follows that the five spheres of Earth, the atmosphere, biosphere,

hydrosphere, lithosphere, and pedosphere are—and have long been—also biologically mediated. These spheres, as they impact the McGregor Range, are the principal focus of study here.

Axiom 4: *All biological agents and processes are basically biochemical and biomechanical in nature.* Where biological agents are acknowledged as important in geomorphologic, pedologic, and Quaternary environmental investigations, they are almost always equated with *biochemical* agents. *Biomechanical* agents, on the other hand, are rarely acknowledged in such investigations. Acknowledging that biochemical *and* biomechanical agents together play key roles in landscape evolution can shed light on some otherwise irresolvable problems in many geomorphologic, geoarcheologic, and soil studies, including this one. On the McGregor Range, biochemical agents are largely expressed as caliche, whereas biomechanical agents are largely expressed as biomantles and as bioturbation vectors that reset 'caliche clocks'.

Axiom 5: *Biomechanical agents cause bioturbation, or sediment and soil mixing by iota. Common manifestations are surface mounds, soil structure, biofabric, krotovina, and, not infrequently, episodically reset or partially reset caliche clocks.*
Bioturbation is a form of pedoturbation, and pedoturbation is a fundamental soil-forming process. Bioturbation in most soils is caused mainly by invertebrates, vertebrates, and plant roots. Expressions of bioturbation are surface mounding, some soil structures, krotovina and biofabric, all of which are abundant in McGregor Range. Krotovina (crotovina) are infilled animal burrows—technically those of fossorial rodents, at least as the term was originally used by Dokuchaev (1883a, 1883b) and Sukachev (1902), but in this report krotovina are considered to be any infilled animal burrow, produced either by vertebrates or invertebrates. Biofabric is soil fabric produced largely by iota (Johnson 1990) and consists of a mix of biochannels, biovoids, biovughs, fecal pellets, and randomly tipped clasts that may have been originally stratified and/or imbricated. Caliche clocks can be reset to zero by some burrowing animals, badgers for example, that can completely destroy calichified subsoils in some profiles, even dense petrocalcic horizons.

Axiom 6: *The number of krotovina observed in an exposure is invariably less than the number that have actually been produced and does not reflect the aggregate bioturbation per unit of time. Over time, some krotovina become indistinct, some become invisible, and new burrowing erases old ones.*
Krotovina are obvious when the material that infills an animal burrow is of a different color than the encompassing soil. For example, dark-colored A horizon materials that infill rodent burrows in whitish caliche produce conspicuous dark krotovinas. But if bioturbation has been between or within similarly colored horizons, or occurs in previously bioturbated and homogenized zones of uniform color—which often is the case on the McGregor Range—krotovina may not, indeed often are not, apparent. Further, because subsoil (B horizon) krotovina that are infilled with A horizon material may be more permeable than surrounding less disturbed subsoil, they function as throughflow zones for meteoric waters during rains and/or snowmelt events. Consequently, where organic matter may have originally given krotovinas a dark color, it gradually fades and lightens via oxidation-reduction, leaching, and pH/eH bleaching. It also may become masked by carbonate overprints. Old krotovina are also destroyed by later burrowing. Thus, the krotovinas present in a soil when described may be an inconclusive indicator of that soil's collective bioturbational history. On the other hand, some subsoil krotovinas—like cicada burrow infillings—may be visually enhanced and fossilized by precipitated calcium carbonate. They then, technically speaking, become caliche pseudomorphs after cicada burrows and are in fact common features of many McGregor Range soils.

Axiom 7: *Inasmuch as soil is the epidermis of landforms, they are one and the same.*
Landforms and soil are part of a natural whole, and they are considered as such here.

Axiom 8: *All soils and paleosols (buried soils) are by their very nature unique, polygenetic, and time transgressive.*
Because every soil is unique, polygenetic, and time transgressive, a risk attends correlating them from one geomorphic surface to another, even though it is common practice. It is also risky to apply the relative rates of pedogenesis in one area to another. Each pedon of soil (~ 1 m^2) has a unique history involving an array of interactive ordering and disordering processes, which includes additions, leaching, precipitations, translocations, and bioturbation (sometimes considerable bioturbation as in the case of McGregor Range soils) as well as other processes. In fact, if ^{14}C dates run on carbon-bearing materials collected at increasing depths show commensurately older ages without reversals or aberrancies, it is an unexpected reward!

Axiom 9: *Most reddish sand in the southern Tularosa Basin ultimately derives from early and late Paleozoic Bliss, Abo, and Yeso formation redbeds that outcrop in basin-bordering uplands.*
The redbeds produce sediments that wash into the basin as reddish alluvium during stormflows. A portion of this recycled redbed sediment is wind-winnowed via deflation, leaving residual sand on the basin floor as a dynamic by-product, from which dunes form. Some dunes are blown east and northeast onto basin-bordering fans, then washed back down as fluvial sand in a repetitive, iterative process. Some of the sand may be re-winnowed and blown up again, then washed down iteratively, again and again. A portion of the iteratively recycled redbed sediment, however, is episodically buried by fan sedimentation and permanently removed from the iterative system as the basin subsides. Burial and basin subsidence are the removal elements of the Tularosa Basin sand cycle. Weathering and erosion of new sand from Paleozoic strata may resupply all or part lost through burial and basin subsidence.

Axiom 10: *Dune piles, dune sheets, and downwind migrating 'dune trains' are concentrated on the eastern side of the southern Tularosa Basin, especially on the McGregor Range, and while some have episodically accumulated over late Quaternary time, most are historic and are part of an accelerated, human induced Tularosa Basin sand cycle.*
Prevailing winds in the southern Tularosa Basin are from southwest to northeast and east-northeast. As a consequence, basin sand produced by redbed erosion augmented by sediment derived from upwind topsoil erosion ultimately migrates to and accumulates in the eastern side of the basin. Sand accumulation must, however, be offset by sand lost through fan-toeslope burial and basinal subsidence, for otherwise the eastern Tularosa Basin would fill with sand (cf., Axiom 9). Air photos, ground truthing, and backhoe excavations in the Jarilla Bolson (sites 10, 13-16) confirm this axiom.

Axiom 11: *Most coppice dunes in the McGregor Range are historic in age and genetically linked to recent dune sheets and to eroded A horizons of sandy upwind soil; those well stratified are of recent historic origin, whereas those poorly stratified or unstratified are mainly of earlier historic origin, where bioturbation is the destratifying vector.*
Coppice dunes can form quickly, and evidence for this is preserved as recent historic stratification that is confirmed by ^{14}C dating. Bioturbation, mainly by animals and plant roots, may destratify coppices relatively rapidly within decades of their formation, other things being equal. Rates of destratification reflect the kind and relative numbers of bioturbators per coppice dune per unit of time and the rate at which new sand is accreted to coppices (rapid accretion promotes stratification whereas slow accretion may allow bioturbation to keep pace).

Axiom 12: *Alluvium on McGregor Range derives mainly from carbonate rocks and is deposited as carbonate rich sediment. Other things equal, pedogenic caliche forms more quickly in carbonate than in noncarbonate alluvium; in the latter, the sole source of carbonate is eolian dust. Equivalent caliches in each thus do not reflect equivalent rates of caliche formation.*
Except for originally noncalcareous Camp Rice sediments, and some alluvium that derives from igneous areas of the Jarillas, the McGregor Range has exclusively calcareous sediments shed from Otero Mesa and Hueco-Sacramento Mountains. Carbonate sediment is constantly redistributed on the McGregor Range by ephemeral streams on calcareous alluvial fans, by surface wash and meteoric waters on calcareous alluvium and pediments, and by calcareous outfall from local winds and dust devils. Under such conditions pedogenic caliche develops rather more quickly than in noncalcareous alluvium, where source carbonate is mainly from eolian dust. Consequently, using pedogenic carbonate as an age indicator and or correlation tool between such terranes carries attendant risks.

Axiom 13: *Alluvial fans of the McGregor Range are complex units of alluvium, mudflow, and debrisflow deposits, each of which may be partly or wholly imprinted with a soil (or if buried, a paleosol). Soils and paleosols represent long periods of boredom (pedogenesis) whereas alluvial units represent short moments of terror (deposition).*
Subaerial pedogenesis, or soil formation, is an ongoing process. It never stops, though its style and rate may vary with time. Consequently, when water-borne alluvial, mudflow, and debrisflow material is shed from uplands onto lowlands, pedogenesis begins when the terror ends. The vertical sequence of fan sediments on McGregor is represented by alternate episodes of terror followed by long periods of boredom.

Axiom 14: *Faulting and associated structural activity have played key roles in the evolution of major and most minor landforms on the McGregor Range.*
No appreciation of landscape evolution in this part of New Mexico can be realized without an appreciation of this axiom and this fact. On the McGregor Range, bolsons, depressions, escarpments, fan offsets, fan insets, many playas, most stream orientations, most runoff patterns, and indeed the entire structural grain and character of the McGregor bedrock-pediment complex reflect the fundamental role of geologic structure, mainly faulting, and mainly normal faulting.

Concept of Process Vector Analysis: *Process vector analysis weights the relative morphologic effects of two or more geomorphic-pedologic or geoecologic processes.*
The weighting of two or more processes can be shown by means of vector arrows emanating from a common point whose lengths are quantitatively or qualitatively scaled to reflect their relative effects on the landscape. Two examples, one geomorphic and the other pedologic, demonstrate this simple though useful concept. First, if both sheet and wind erosion versus alluvial deposition are episodically occurring concomitantly on an alluvial fan at equivalent efficacies, such that their observed (or measured) morphologic expressions are about the same, then their vector strengths will be equal. But if one process gains dominance over the other, its vector strength becomes commensurately greater, even though the subsidiary process remains important in the evolution of that surface.

A pedologic example is where carbonate that is leached from the A horizon of a soil is precipitated in the subsoil (B horizon) as pedogenic caliche. If the precipitation process, however, is countermanded by constant bioturbation such that no calcic horizon forms, the *biomechanical* (mixing) vector becomes the dominant process whereas the *biochemical* leaching-precipitation vector is subsidiary, even though it also constantly operates on the landscape.

> If data are available, both examples can be quantitatively or semiquantitatively expressed using scaled vectors. If data are not available, then the relative vectors can be qualitatively expressed (inferred), and expressed in language or in schematic form. The vector analysis concept offers a different viewpoint or perspective in rational analysis. Embedded in the vector analysis concept are the linked notions that: (1) the vector arrows of all geomorphic and pedologic processes dynamically change and vary with time; and (2) subsidiary process vectors—even though subsidiary—play important genetic roles on the landscape, and can establish or reestablish dominance if conditions allow.

The concept of process vector analysis is a way to make sense of complex soil-geomorphic and geoecologic relationships, and its conceptual utility is reflected in many of the interpretations made in this report.

CAVEATS

Several caveats are in order. One is that the McGregor Range is a very large area, and the ideal geomorphic, pedologic and geoarcheologic assessment and geomorphic mapping project would require drilling and backhoeing more sites than is economically feasible or environmentally justifiable. Other things equal, the more backhoe pits dug the better might be the geomorphic assessment. But, every backhoe pit is an intrusive artificial disturbance of the natural landscape, and thus technically environmentally deleterious. Nevertheless, it is believed that a sufficient number of backhoe pits and drill cores were emplaced on McGregor during this study to create, in conjunction with other environmental and intellectual resources, a credible overview of how the landscape evolves.

By the same token, mapping the McGregor Range has been a challenging task. As indicated, mapping was accomplished using color and black-and-white air photos, and color infrared air photos in conjunction with USGS orthophotomaps and topographic maps, supported by ground truthing. The more time spent ground truthing maps the more accurate they should be, other things equal. However, ground truthing every small area of the entire reservation was not temporally or economically possible. Slight errors at boundaries between geomorphic surfaces may have crept in, but the maps are otherwise reasonably accurate, as accurate as the methodologies employed allow.

CHAPTER 3
GEOECOLOGICAL ASSESSMENT OF MCGREGOR RANGE

ENVIRONMENTAL OVERVIEW

This section presents an overview of what is known about the general physical and cultural environment of the McGregor Range. It summarizes relevant environmental studies that have been conducted on the base, or in the region if the topic bears on the base. It also summarizes overview information learned in the field and elsewhere during the course of this study.

Brief Cultural History

Human habitation along the Rio Grande valley spans over 12,000 years in what is defined as the Jornada Mogollon culture region (applying primarily to the ceramic period), covering the Hueco Bolson, the Tularosa Basin and the Jornada del Muerto (Figure 5). During this time, several distinct culture periods have been recognized, including the Paleo-Indian, Archaic, Formative, and Historic periods. A brief summary is included herein; for more in-depth studies of the cultural history of the region, Beckes (1977), Beckes and Dibble (1976), Carmichael (1988), Mauldin (1966), Russell (1968), and Whalen (1978) are recommended.

The Paleo-Indian period (<10,000 B.C.–6000 B.C.) is divided into three major traditions, based on projectile point typologies: Clovis, Folsom, and Plano. During this time nomadic groups hunted dwindling herds of megafauna, while major environmental changes were taking place, bringing a warmer, drier climate to the area.

The Archaic period (6000 B.C.–A.D. 200) is divided into four major phases based on projectile point typologies and radiocarbon dates. These four phases consist of Gardner Springs (6000 B.C.–4300 B.C.), Keystone (4300 B.C.–2600 B.C.), Fresnal (2600 B.C.–900 B.C.), and Hueco (900 B.C.–A.D. 200). Foraging efficiency apparently increased during the Archaic period as the usefulness of more plant species and the technology to process them were developed. Textiles slowly replaced the use of large mammal hides, and nomadic lifestyles slowly gave way to a more sedentary, horticulturally influenced subsistence. As domesticated plants came into use, maintenance of these resources required constant attention from at least a few individuals. Base camps, including some type of habitational structures, became more prevalent.

The Formative period, defined primarily by the advent and florescence of ceramics, is evident in the area between A.D. 200–A.D. 1400. This period is generally divided into three phases: the Mesilla (A.D. 200–A.D. 1100), Doña Ana (A.D. 1100–A.D. 1200), and El Paso (A.D. 1200–A.D. 1400). The Mesilla

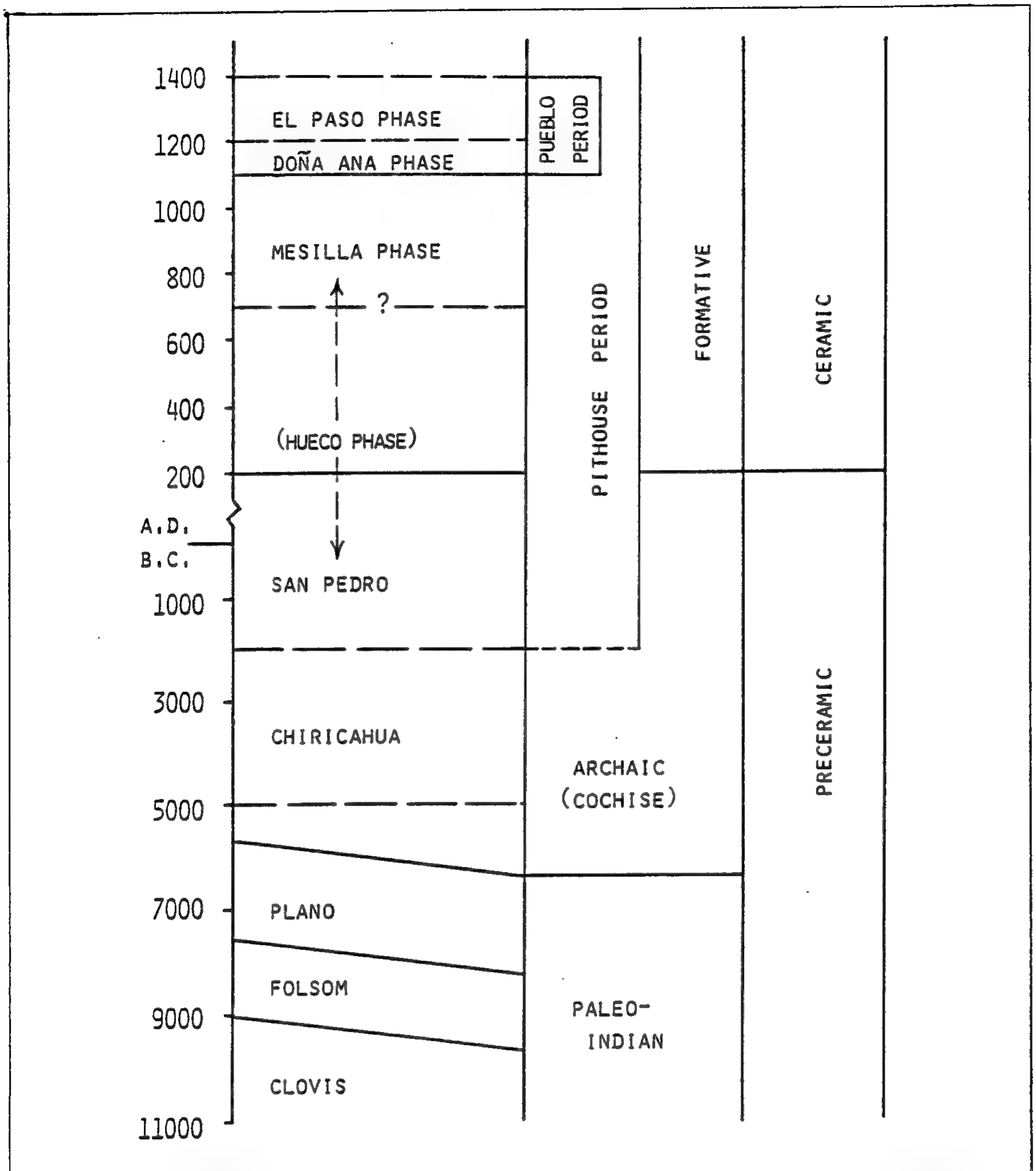


Figure 5. Cultural sequence for the Jornada Mogollon area, including the McGregor Range (after Carmichael 1983:Figure 3).

phase is defined by the production of plain brownware pottery. The increased use of cultigens and the increased storage potential provided by ceramic vessels contributed to the inception of a sedentary, village lifestyle during this phase. Structural remains typically consisted of roof or ramp entry pit-structures. Decorated tradewares, predominantly Mimbres Boldface, are commonly included in associated ceramic assemblages of the latter part of the Mesilla phase. Pinched and direct brownware rim forms are usually attributed to the Mesilla phase and are often relied upon for temporal assignments, particularly in the absence of decorated tradewares. The Doña Ana phase represents a transitional period when pithouses were replaced in favor of pueblo-style housing. Decorated tradewares, predominantly Mimbres Classic, are commonly

included in associated ceramic assemblages. A variation in local brownware rim forms correlates with the Doña Ana phase, when rims appear to have been intentionally thickened and flattened. The El Paso phase essentially represents the Pueblo period of Jornada Mogollon prehistory. Although several structure types have been reported, contiguous, surface room blocks of puddled adobe typify structural remains. El Paso Polychrome jars with everted rims are associated with this phase. A specialized, intensive farming adaptation has been suggested for the El Paso phase, yet hunting and gathering continued to play an important role in subsistence. Trade contact with surrounding regions reached its peak during this phase, as evidenced by ceramic tradewares from central New Mexico, as well as eastern Arizona and northern Mexico. The end of the El Paso phase is marked by the depopulation of the Jornada region by pueblo people. What happened to these people and where they might have gone is not fully understood.

When the Spanish *entrada* began in 1535, the area was inhabited by what were called Manso, Suma, and Jumano Indians. In 1598, Don Juan de Oñate took possession of the land in the name of the Spanish crown, calling the area El Paso del Norte. In 1630, Spanish missionaries began the religious conversion of the native Manso Indians. In 1680, as a result of the Pueblo Indian Rebellion, the Spanish were driven out of New Mexico and retreated south to El Paso. This revolt had a dramatic impact upon the area. Within a month, several thousand Spanish and Pueblo Indian refugees had arrived in the El Paso area. This area became the northernmost outpost of New Spain until the reconquest of Santa Fe by Governor Don Diego De Vargas in 1692. From 1692 until the end of Spanish rule in 1821, the El Paso area was largely a series of missions and Indian settlements under the control of Franciscan missionaries and Spanish officials.

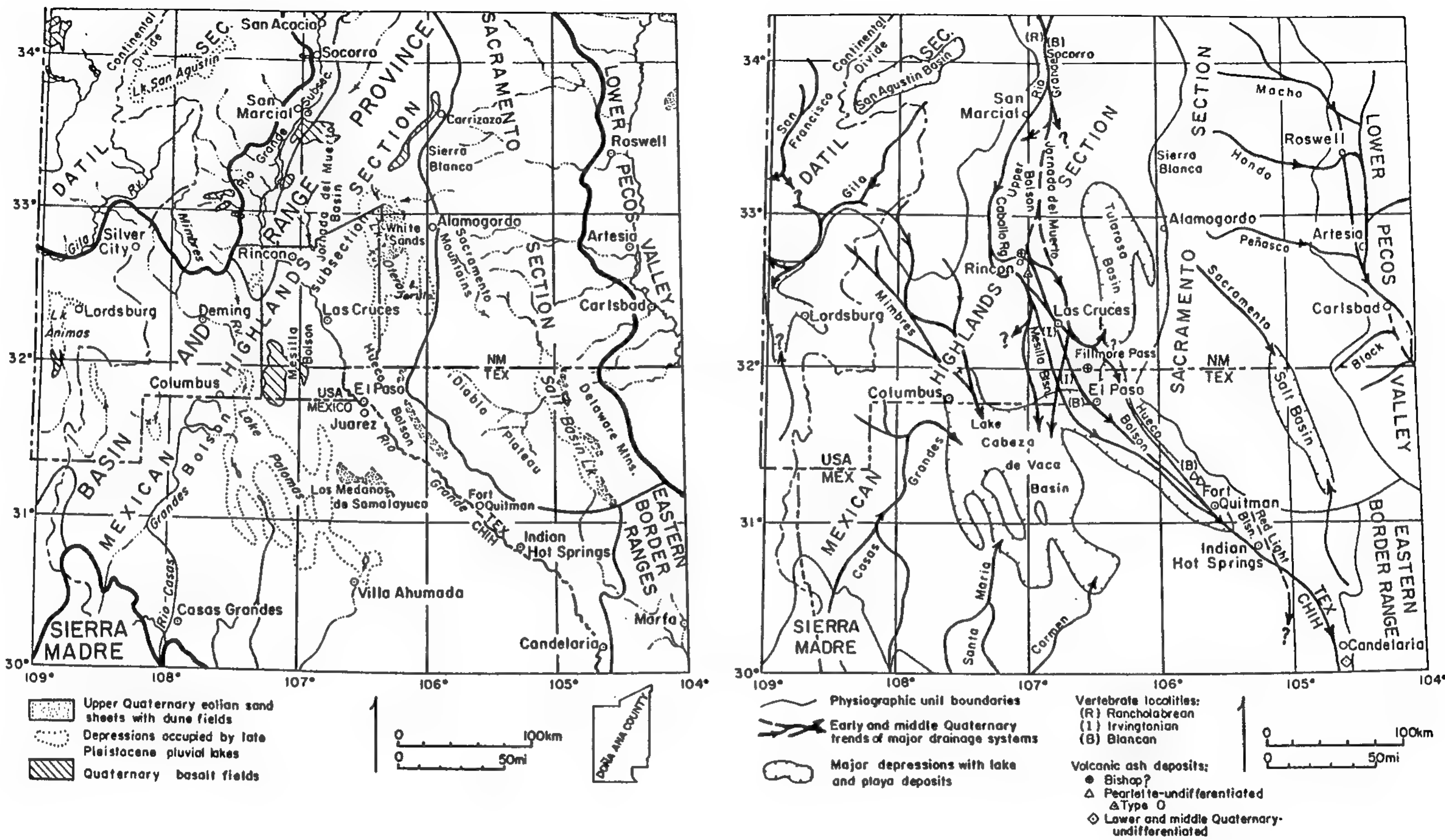
In 1821, Mexico won its independence from Spain, bringing the El Paso area under Mexican rule. Following the Mexican-American War, the Treaty of Guadalupe Hidalgo was signed in 1848, bringing the area north of the Rio Grande under United States control. Following this, the El Paso area population grew tremendously as transportation methods improved, first with wagon roads in use from 1853 to 1880, then with railroads in 1881.

A military presence was established in the El Paso area in 1849, to protect the area from Indian attacks. Fort Bliss was formally established in 1854, and—after several abandonments and reestablishments in different locations until 1893—it is now found in its current location.

Regional Setting and Physiography

The McGregor Guided Missile Range occupies the northeastern part of Fort Bliss, a large U.S. Army military reservation with headquarters in El Paso (see Figures 1 and 2). Its 1,075-square mile area (2,784 km^2), larger than the State of Rhode Island (1,058 sq mi), lies within the dry Chihuahuan desert of southcentral New Mexico, western Texas, and northern Mexico. It is near the eastern boundary of the Basin and Range Physiographic Province of western North America (Figure 6). It straddles the boundary of two of its major divisions, the Mexican Highland Section (the lowland portion of which McGregor is a part, i.e., Tularosa Basin), and the Sacramento Section which encompasses the upland Sacramento-Otero-Hueco portion (Fenneman 1931; Thornbury 1965). The Otero Escarpment is the boundary between them. Hawley referred to the Tularosa Basin portion as the Bolson Subsection of the Mexican Highland Section (Hawley 1975; see Figures 1 and 6 for the physiographic provinces and subdivisions, the major present drainages and paleo-drainages, pluvial lakes, dunefields, major ash and vertebrate deposits, and other pertinent contexts of northern Mexico, New Mexico, and West Texas).

In terms of regional and local physiography, McGregor is bound on the east by Otero Mesa, on the northeast by the Sacramento Mountains, and on the northwest by the Jarilla Mountains, which cover some 20 square miles (32 km^2), and the alkali flat lowlands to the north of the Jarilla Mountains. The Tularosa Basin lies within the western part of McGregor, and the Hueco Bolson and Hueco Mountains lie on its southern border.



a b

Figure 6. Physiographic maps of southcentral New Mexico and northern Chihuahua, Mexico: (a) physiographic provinces, subdivisions, major stream systems, pluvial lake basins (Lake Jarilla was added), and dune and basalt fields; (b) early and middle Quaternary paleodrainages, undrained depressions, volcanic ash, vertebrate faunal localities, and modern physiographic subdivisions (modified Hawley 1975a).

A subbasin of the Tularosa Basin occurs east and northeast of the Jarilla Mountains, called here the Jarilla Bolson. The bolson narrows to the southwest and becomes the Jarilla Gap, structurally set between Hueco limestone to the north and south (see Figure 2). The Jarilla Bolson widens to the north where it is onlapped by alluvium emanating from fans along the Sacramento Mountain escarpment. To the north and northwest it merges with alkali flat lowlands in the Tres Hermanos Buttes area.

Otero Mesa is a major upland tableland that dominates the east and northeast parts of McGregor. It is dominated by Permian Hueco limestones that dip gently to the east, which control the surface and subsurface water flow in that direction.

Politically, the southern border of the McGregor Range is defined by the New Mexico-Texas state line, which straddles and passes through the 6,700-foot high Hueco Mountains. The western border of McGregor Range is defined by the El Paso and Southwestern Railroad in the Tularosa Basin, which parallels U.S. Highway 54 for the most part. Its northern boundary extends into the foothills of the Sacramento Range, a range which culminates to the north in the majestic 12,000-foot high (3,658 m) Sierra Blanca (see Figure 1). The Sacramento Mountains, Otero Mesa, and Hueco Mountains form the upland part of the McGregor reservation, and the Tularosa Basin and Jarilla Bolson the basinal portions, with the west-facing Otero Escarpment defining a wide boundary between them. The eastern border of McGregor extends onto Otero Mesa, and its far northeastern corner extends beyond the mouth of the Sacramento River into the eastcentral foothills of the Sacramento Mountains. The Jarilla Mountains lie on the westcentral side of the McGregor Range, and the northwestern limits of the base extend into gypsiferous alkali flatlands south and west of Alamogordo.

The Tularosa Basin is an intermontane basin some 120 miles long by 35 miles wide (192 by 56 km). It is a down-dropped graben which lies between the Organ-San Andres mountains on the west, the Otero Mesa and Hueco-Sacramento-Sierra Blanca mountains on the east, the Chupadera Mesa on the north, and the Hueco Bolson on the south (see Figure 1).

Climate

General

The Chihuahuan desert is typified by an arid to semiarid continental climate with warm relatively dry winters and hot monsoonal (moist) summers; most precipitation is in summer. Inasmuch as the military reservation lies partly in a basin, partly on a mesa, and partly in the mountains, the nature of the climate is somewhat variable depending on location within the base. The basin portion averages slightly more than 4,000 ft elevation (1,219 m), whereas the Mesa portion lies between 5,000 and 5,400 ft (1,524-1,646 m), rising to higher elevations that approach 6,000 ft (1,829 m) in the Hueco Mountains, and 7,000 ft (2,134 m) in the Sacramento Mountains. A temperature and precipitation gradient thus exists between the basin, the mesa, and the surrounding higher lands, the basin being drier and hotter, the uplands more moist and cooler. Much of the climatic overview which follows is based on the data of Appendix B, Climatological Data published monthly by NOAA, on summaries by Houghton (in Derr 1981), and on personal interviews with local ranchers and professionals.

Temperature

Mean annual temperatures range from 58 to 62 degrees Fahrenheit (14.4-16.7° C) depending on location (see Appendix B). Summers are warm to hot, sometimes very hot, winters normally warm punctuated by cool days, rarely below 20° F, but in upland areas some winter periods can be colder. In the basin and on the

Mesa, most days are hot in the summer between mid-May to mid-September, often with daytime highs above 90° F, sometimes well above. The highest temperature of record was 116° F (46.7° C) at Orogrande on July 14, 1934. The average number of days with freezing temperatures ranges from 80 to 100, mainly between November and April. Few days remain freezing, and rarely are 0° F temperatures met. The lowest temperature of record in the basin was -14° F at Alamogordo on January 11, 1962.

Precipitation

Average annual precipitation ranges between 8 to 11 inches (20-28 cm) in the basin and from 12 to 20 plus inches (30-51 cm) in the uplands, most of which falls as rain during the six summer months (May-October, see Appendix B). But precipitation can be quite variable from year to year. For example, El Paso has an average annual precipitation of about 8.6 inches (22 cm), but during the five-year period 1880-1884 the average was far higher (14.6 in, 37 cm), with two of those years each receiving 18+ inches (46+ cm), but the next eight years (1885-1892) averaged only 6.9 inches (18 cm), with all years but one below normal (see Appendix B). Wetter than average years followed by drier than average ones in the Tularosa Basin were hard lessons during the pre-1900 pioneer settlement period, as will be noted in sections below.

The principal moisture source during summer is from the Gulf of Mexico linked to airflow around the Bermuda Highland, and to a lesser extent from the Gulf of California and eastern Pacific Ocean. This moisture arrives on monsoonal winds drawn from the ocean to the heat-induced low pressure system that develops during the high sun season over the southwestern USA. Most precipitation is from summer thunderstorms that are typically brief, though sometimes very intense. An average of 45 thunderstorms per year impacts the area, and flash floods are not uncommon. On June 30, 1995, nearly three inches (8 cm) fell in 30 minutes, which washed a car off Highway 45 into a depression several miles south of Orogrande (personal communications with Pat Johnson, weather recorder, and Al Tengelitch, proprietor of Oro Chico Cafe, Orogrande, NM, 1996). The main moisture source in winter is from eastward moving cyclonic storms that sweep across western North America from the Gulf of Alaska. Some of this moisture falls as snow, usually lightly in the basin, with more on the uplands. Snow rarely develops as drifts on Otero Mesa but with occasional copious amounts in the mountains.

Humidity

Relative humidity during the high sun season is generally low except during storms, ranging from 40 to 65 percent in the early morning hours, 25 to 35 percent in afternoons of the rainy season, and from 15-25 percent in afternoons of the drier springs. These are averages, however, and at any given time the humidity can be very low and, less commonly, very high. In the late spring, summer and fall evaporation is very high, up to 100 inches per year in Class A pan measurements.

Wind

Winds are prevailing from the west and southwest, and though they average about 10 mph they are often gusty and variable during spring and summer months. Figure 7 shows wind roses for Holloman AFB near Alamogordo and for El Paso International Airport, and Figure 8 shows long term wind tracks in the Tularosa Basin. Occasionally, reverse winds blow from the east and northeast, out of the Sacramento Mountains and off the Otero Mesa and across the Tularosa Basin. Twice these reverse winds were observed during the summer of 1996, the wind directions made apparent by streaming dust plumes. In one case the point source of dust was Oliver Lee's Thousand Acre Farm (Ditch Camp) on the upper midslopes of Grapevine Canyon fan (Figure 9, see Pipeline Canyon quad).

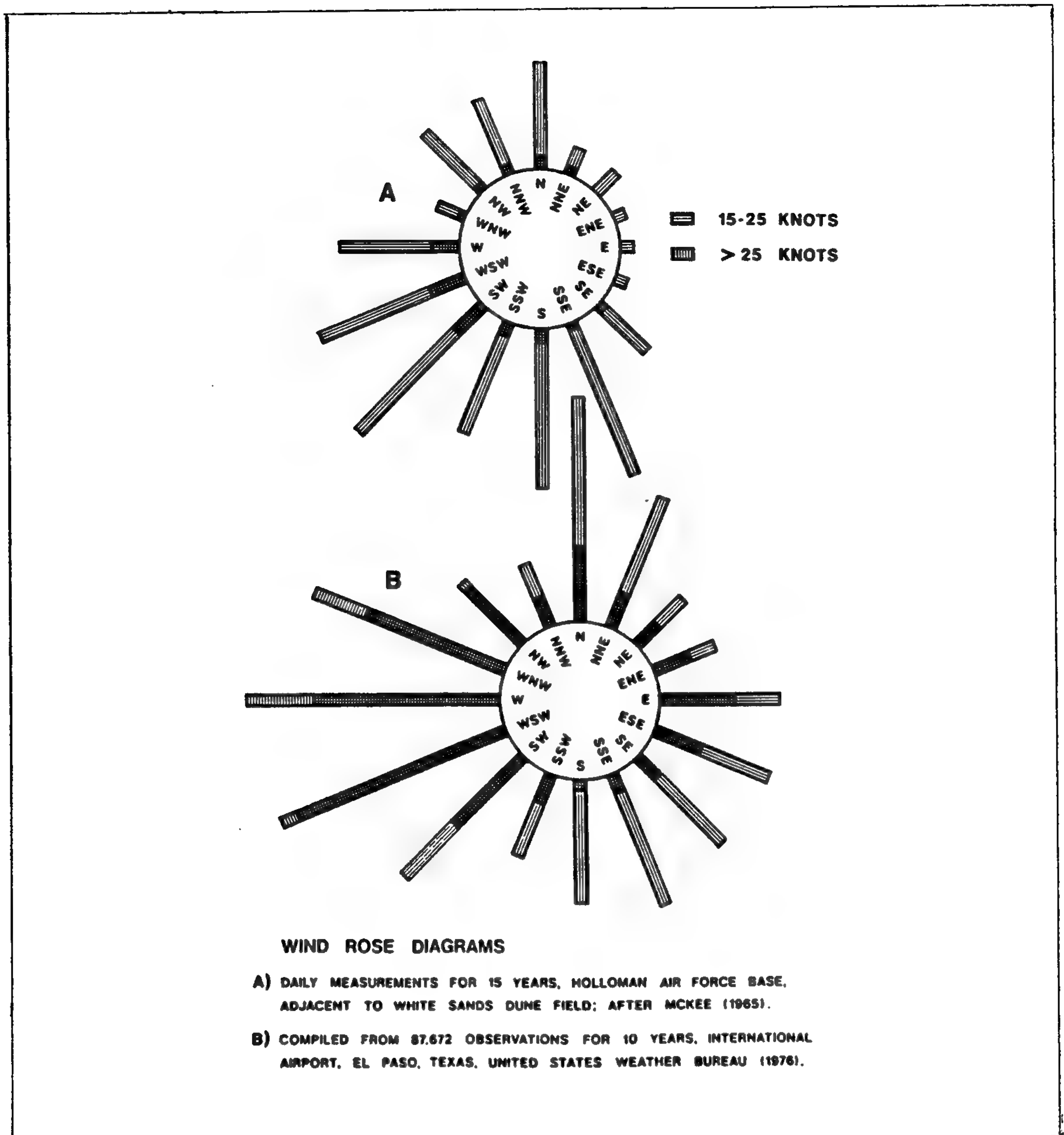


Figure 7. Wind roses for Holloman Air Force Base near Alamogordo and for El Paso International Airport (after Pigott 1977).

Another example of reverse winds was realized when color air photos taken between December 11, 1985, and February 1986 revealed a conspicuous area of McGregor bare and free of vegetation, and very obviously wind eroded. Soil dunes with trailing tails to the west indicate that erosion and deposition were by easterly winds. The wind-eroded area stretches from the eastern McGregor fence line near Bassett Lake west almost to the Hackberry Tank area (Mountain Tank, Owl Tank Canyon W, and Desert NE quads). This area is shown as being well-vegetated on color infrared photos taken three years earlier (September 11, 1982). This wind-eroded area with its tell-tale downwind (west directed) dune tails is outlined by dots on the Mountain Tank and Desert NE quads. Another set of eolian soil plumes that cover a much smaller area on the same photos occupies the southwest part of Otero Mesa South quad, but the plume tails indicate a NNW wind during that erosive episode. Otero Mesa ranchers Charlie Lee and Pete Atkins explained that because that

area (the Ivan Grey corner) had developed an exceptionally thick grass mat in the early 1980s, it had been burn-managed with fires estimated to have been set in 1985 or 1984. Obviously burn-managing sometimes has unforseen consequences—soil erosion by wind.

On McGregor dust is entrained by prevailing west and southwest winds, by reverse winds, and by dust devils. Dust devils are common especially during summer months when convectional heating of the ground is at a maximum. At such times dust columns not infrequently rise many hundreds of feet into the air, and several may be seen at any given time, particularly in afternoons (see Figure 9). Inasmuch as practically all of the soils and surfaces are calcareous, and the area north of the Jarilla Mountains strongly gypsiferous, episodic rains of calcareous dust, sometimes gypsum-laden, can fall across McGregor during spring, summer and fall periods, and sometimes during winters as well. On the afternoon of March 13, 1996, while traveling from Orogrande to El Paso on Highway 54, the sky above the southern Tularosa Basin was so thick with dust that the sun was obscured and darkened, as in a solar eclipse (see Figure 9).

Prevailing southwest winds are documented at El Paso Airport and at Holloman Air Force Base (see Figure 7), but they are also documented by both the abundance of dune piles along the eastern side of the Tularosa Basin and by the general orientations of lunettes situated downwind from playas (cf., Desert, Orogrande N & S, Pipeline Canyon, and Tres Hermanos quads). Historic dune piles migrate slowly downwind as rippled and lobate-shaped dune trains so that their general directions can be easily perceived (see Figure 8). The long-term prevailing wind pattern for the southern Tularosa Basin is confirmed by the locations of dune piles and by obvious movements of the dune trains, and on the orientations of downwind playa lunettes.

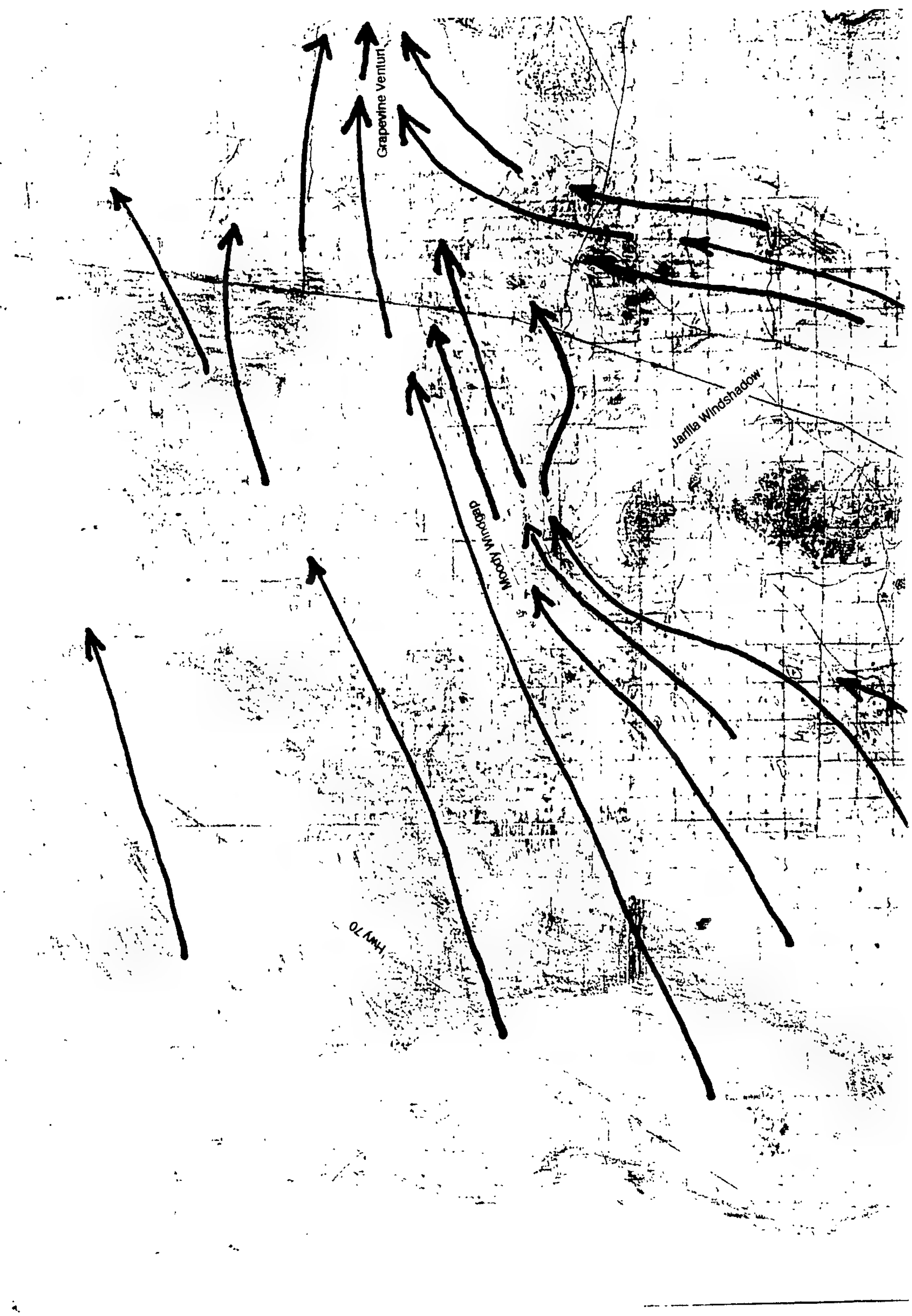
The Jarillas Mountains function as an effective windshadow, with dune trains migrating around them, through the Jarilla Gap on the south and the Moody Lowlands on the north (see Figure 8). The lee, wind-shadowed eastern side of the Jarillas is essentially sand free, except for one thin ribbon of sand that saltates through Sand Gap just north of Monte Carlo pass. Large dune trains, however, do wind-creep through the Jarilla Gap then north across the Jarilla Bolson floor through the Benton Well-Wilde Well-Cox Well area, ultimately onto the Culp-Grapevine Canyon fans. Dune trains in the Moody Windgap move ENE also onto the Culp-Grapevine Canyon fans. Thin sheets of sand also ascend and invade the eolian-impacted Hueco Bedrock Finger limestone hills south of the Jarilla Gap.

Animals

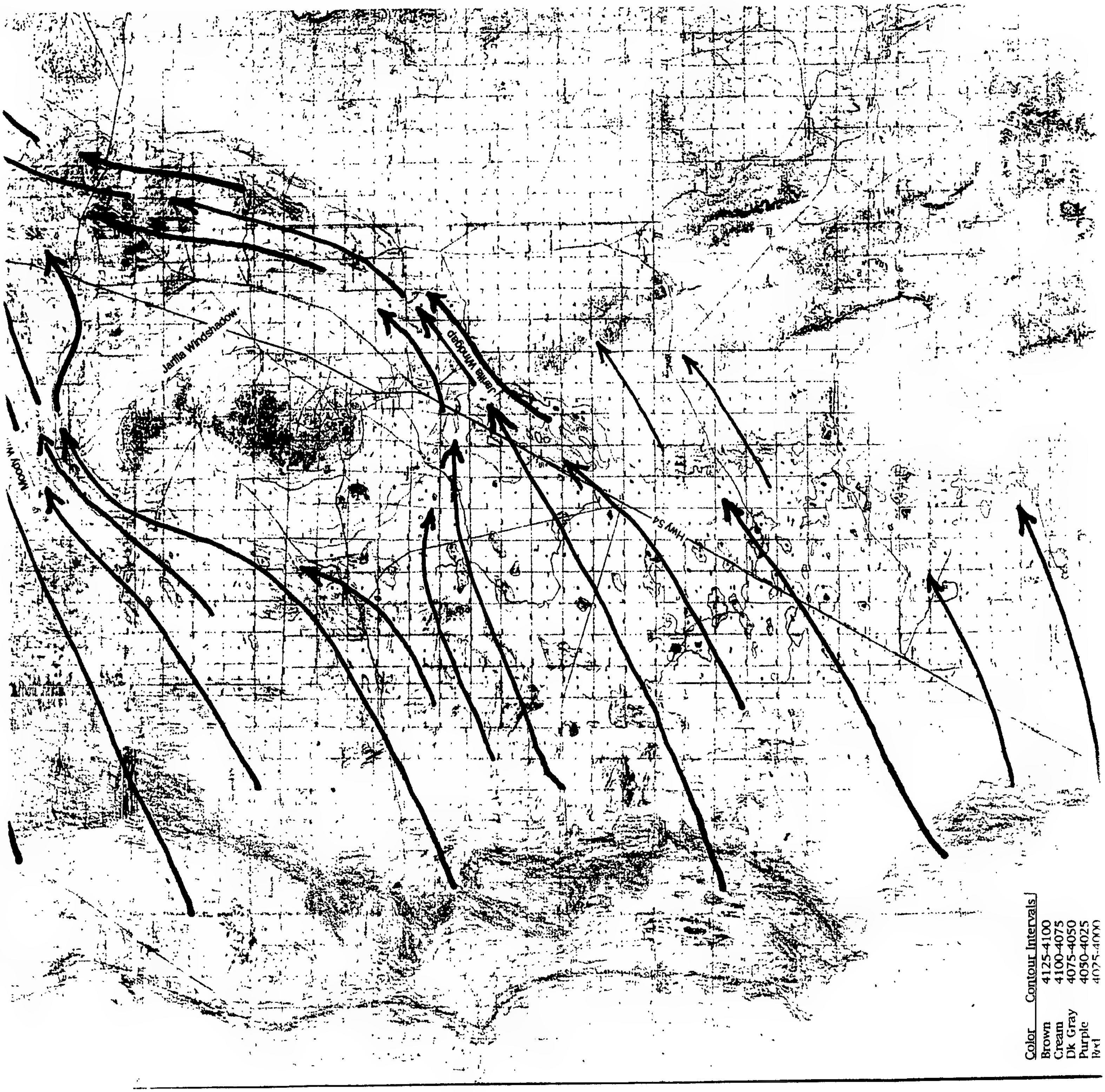
Prehistoric Animals

Prehistoric, now extinct animals such as mammoths, ground sloths, camels, and many other forms were once common in southcentral New Mexico in late Pleistocene and possibly early Holocene time (Harris 1977; Van Devender 1987). And while exact temporal information is somewhat blurred, when most of these species were living in and around the McGregor Range, early humans were living in the region too. As mentioned earlier, evidence for Paleo-Indians has been recorded on McGregor Range (Beckes 1977a; Beckes and Dibble 1976), and at nearby Moody Playa in the Moody Lowlands north of the Jarilla Mountains (Russell 1968), and Pendejo Cave records a long history of human habitation and animals. According to Chrisman et al. (1996), some 35,000 animal bones, representing at least 96 species and including many extinct ones such as species of *Aztlanolagus*, *Bison*, *Camelops*, *Equus*, and *Hemiauchenia*, have been excavated from Pendejo Cave.

That extinct animals lived in the area is further evidenced at Bishop Cap in the southern Organ Mountains, a well-known extinct animal site (Bryan 1929). Mammoth tusks are present in Davies Lake bottom sediments, as observed by the writer in fall 1995 in the company of Dr. Curtis Monger and field assistant D. N. Johnson. In March 1996 the writer and field assistant Johnson also observed numerous instances of


Grapevine Venturi
Jarilla Windshadow
Moody Windgap
Hwy 70

1


Jarilla Windshadow
Jarilla Windgap
Hwy 54
Moody W...
Color Contour Intervals
Brown 4125-4100
Cream 4100-4075
Dk Gray 4075-4050
Purple 4050-4025
Red 4025-4000

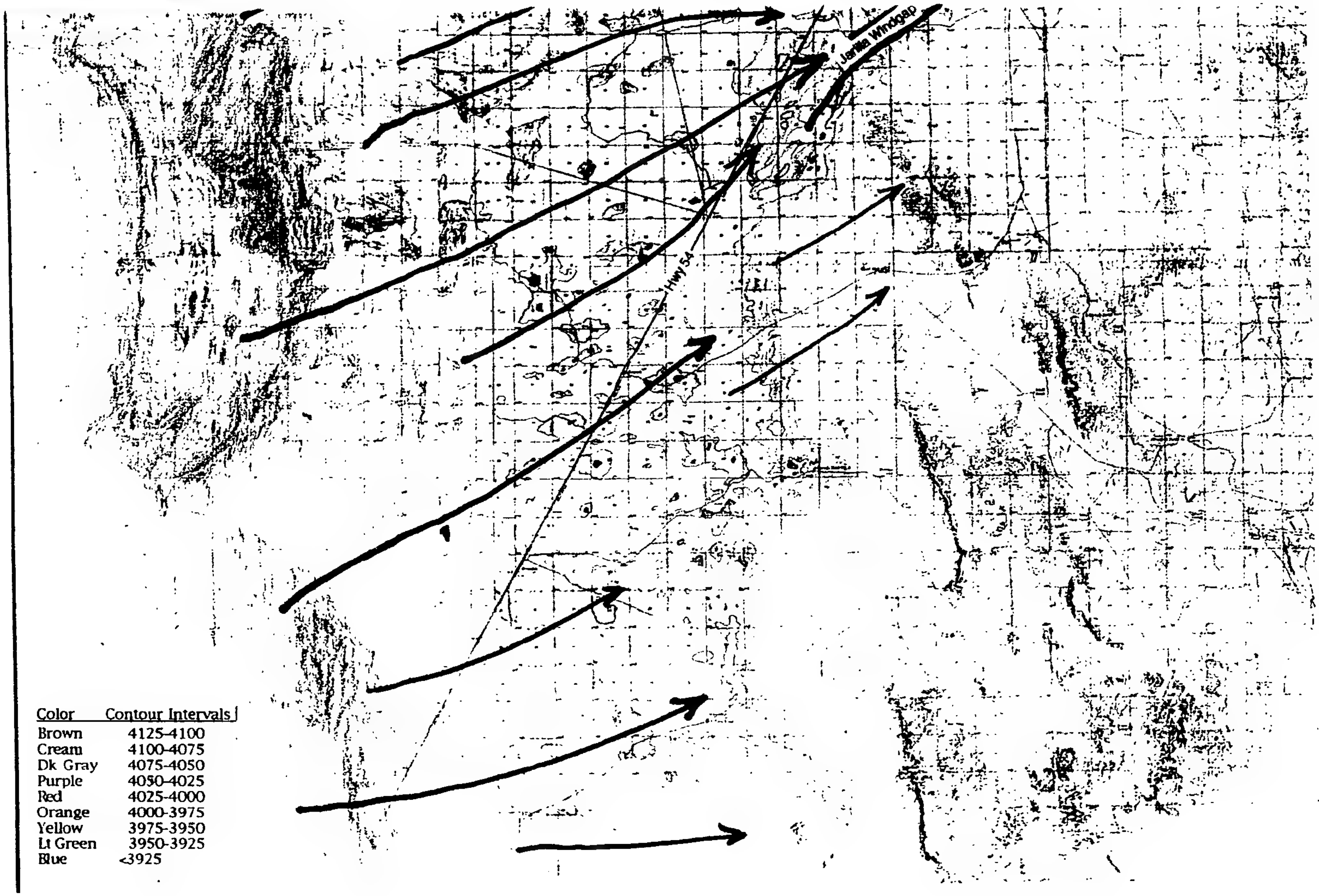


Figure 8. Long-term wind streams for the southern Tularosa Basin based on lunette and dune train tracks and on dune pile locations (contour intervals are in feet).

3

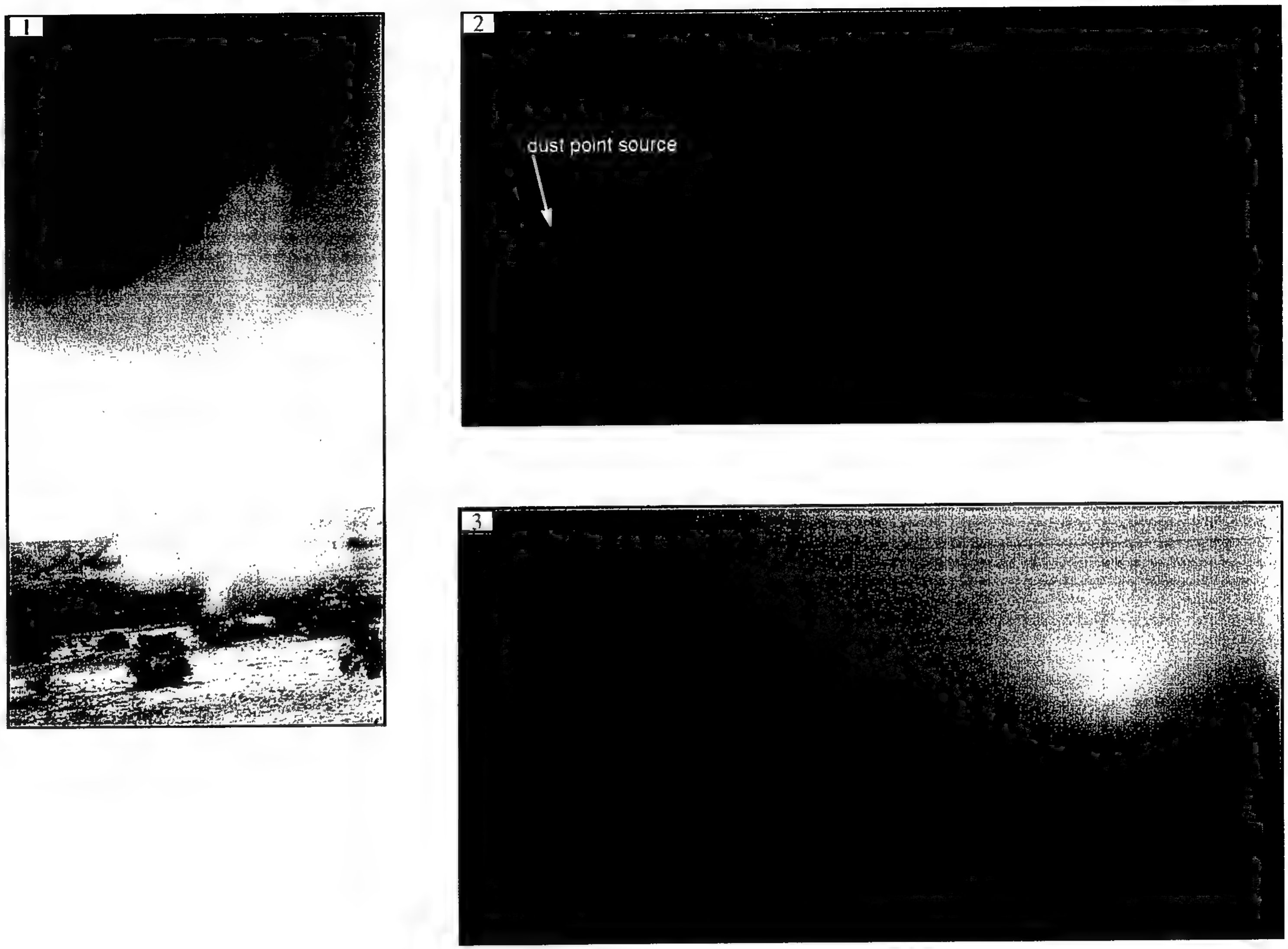


Figure 9. Dust in the Tularosa Basin, NM: (1) dust devil carrying calcium carbonate-rich dust from Grapevine Canyon fan, June 5, 1996; (2) dust blowing southwest from Grapevine Canyon fan, June 10, 1996 (photo taken from Hwy 54); (3) dust storm of March 13, 1996, from Hwy 54 west to Organ Mountains (note sun and mountains invisible).

highly polished, rubbed surfaces around the north side of the Hueco Tanks syenite pluton. The polish is on convex rock edges only and occurs up to 14 ft above ground level, no higher. This is much higher than domestic livestock can rub. Only mammoths and or equivalent-sized animals, such as camel, *Megatherium* ground sloth, and the like, could have produced the polish; large animals living elsewhere today (e.g., elephant, bear, bison, camel, giraffe, etc.) are inveterate rock rubbers. Case hardening, apparently caused by many millennia of rubbing activity, apparently served to preserve the rock polish from weathering and/or spalling. Such polish also characterizes protruding edges of a small syenite pluton upslope (south) from Pluton Pit, site 46 (near Lake Tank, Desert SE quad). Other igneous intrusions in the Hueco Mountains portion of McGregor may show edge polish, but they were not examined. (The limestone bedrock of the McGregor Range would not preserve such polish.) Rock polish attributed to extinct North American animals is not unique to New Mexico, for the writer has observed such in North Dakota and Kansas, as have others elsewhere (Bretz 1946; Schoewe 1932).

Recent (Historic) Animals

Recent (historic) land mammals that presently live, occasionally live, or once did live in the McGregor Range environs are listed below by animal group (from Olin and Thompson 1982):

Tayassuids:	collared peccary (*Dicotyles tajacu*)
Didelphids:	Virginia opossum (*Didelphis virginiana*)
Dasypodids:	nine-banded armadillo (*Dasypus novemcinctus*)
Cervids:	desert mule deer (*Odocoileus hemionus*); Sonora white-tailed deer (*Odocoileus virginianus cousi)*
Bovids:	desert bighorn sheep (*Ovis canadensis mexicana*)
Antilocaprids:	pronghorn antelope (*Antilocapra americana*)
Felids:	jaguar (*Felis onca*); mountain lion (*Felis concolor*); bobcat (*Felis rufus*)
Canids:	gray wolf (*Canis lupus*); gray fox (*Urocyon cinereargenteus*); kit fox (*Vulpes macrotis*)
Procyonids:	Mexican raccoon (*Procyon lotor mexicanus*); coati (*Nasua nasua*); ringtail (*Bassariscus astutus*)
Mustelids:	badger (*Taxidea taxus*); black-footed ferret (*Mustela nigripes*); hooded skunk (*Mephitis macroura*); striped skunk (*Mephitis mephitus*); hognose skunk (*Conepatus mesoleucus*); spotted skunk (*Spilogale gracilis*)
Leporids:	Blacktail jack rabbit (*Lepus californicus*); antelope jack rabbit (*Lepus alleni*); desert cottontail (*Sylvilagus audubonii*)
Rodents:	porcupine (*Erithizon dorsatum*); white-throated woodrat (*Neotoma albigula*); valley pocket gopher (*Thomomys bottae*); cactus mouse (*Peromyscus* spp.); pocket mouse (*Perognathus* spp.); grasshopper mouse (*Onychomys* spp.); bannertail kangaroo rat (*Dipodomys spectabilis*); cliff chipmunk (*Eutamias dorsalis*); Harris' antelope squirrel (*Ammospermophilus harrisi*); roundtail ground squirrel (*Spermophilus tereticaudas*); rock squirrel (*Spermophilus variegatus*); spotted ground squirrel (*Spermophilus spilosoma*); blacktail prairie dog (*Cynomys ludovicianus*)
Insectivores:	gray shrew (*Notiosorex crayfordi*)

Bears live (or formerly lived) in the area as indicated by map toponymy (cf., Bear Wallow Springs, Bear Creek, Bear Spring, etc., on Rogers Ruins and adjacent quads). Mountain lions live in the area, and one was seen consuming a deer kill on McGregor in early 1996 by a Fort Bliss wildlife researcher (who requested anonymity, personal communication 1996). Mule deer were regularly seen during the course of this study (five at Benton Well on June 9, 1996, a road kill near McGregor Base Camp in July, plus others). Pronghorn antelope were observed on Otero Mesa and historically were present in the Tularosa Basin (note Antelope Tank near Highway 70, SW of Point of Sands). Eighteen oryx were observed on July 27 at

Vertisol Playa in the basin, and many others observed a month earlier at the Ivan Grey homestead just west of Bassett Lake.

In terms of their total mechanical impacts on the archeology, ecology, geoecology, geomorphology, and soils of McGregor Range, few animals surpass mustelids (badgers), rodents (gophers, ground squirrels, prairie dogs, kangaroo rats) and soil insects (cicadas, beetles, ants, termites). Their burrowing legacies lie widely on the land and are expressed as krotovinas in all soils and as surface mounds of soil and gravel scattered ubiquitously across the base. The author and his coauthors have emphasized in several published works how the biomechanical side of the biotic factor has been traditionally underplayed in soil-geomorphological and archeological work (Johnson 1990a, 1993b; Johnson et al. 1987). In this report, these processes, specifically by mustelids, rodents and insects, are addressed at a level commensurate with their importance. Limited literature of their burrowing behavior is presented here.

The biomechanical behavior of badgers has been addressed by Balph (1961), Errington (1937), Lindzey (1976), Long and Killingley (1983), Moore (1990), Neal (1986), Reichman and Smith (1990), Roper (1992), Sargeant and Warner (1972), and Snead and Hendrickson (1942). Badgers burrow for food (rodents, honey ants) and for living and denning purposes (burrow systems are called setts). Their burrowing abilities in terms of speed, volumes moved per unit of time, and impact on the ground and environment is legendary (Moore 1990; Long and Killingley 1983; Neal and Roper 1991; Platt 1975). Their presence on the McGregor Range was noted in all environments except soilless bedrock areas and playas. Their role in soil-sediment disturbance is treated under the Geomorphology and Soils section.

The biomechanical behavior of gophers, ground squirrels, kangaroo rats, and prairie dogs—all rodents that occur on the McGregor Range—has been addressed by Bocek (1986, 1992), Grinnell (1923), Hawbecker (1940), Johnson (1989), Mohr and Mohr (1936), Vorhies and Taylor (1922), Seton (1893, 1904), Wallace (1991), and many others. Much of this literature has been summarized by Reichman and Smith (1990) and Meadows and Meadows (1991). The collective burrowing roles of rodents on the McGregor Range is enormous, and, like badgers, the only places their effects were not observed was on soilless bedrock and some playas. They too are treated below in the Geomorphology and Soils section.

The behavior of soil-dwelling insects has been summarized by Benckiser (1996), Elm (1991), Kevan (1955), Kühnelt (1961), Lee and Wood (1971), and many others. Fossorial insects also have impacted the McGregor Range soils and sediments in fundamental ways. Ant and beetle mounds, termites mud sheaths, and cicada nymph burrows are ubiquitous and in abundance in all area soils. In some profiles cicada nymph burrows, for example, completely dominate the physical structure and character of the soil. Because they do, and because most readers are probably not familiar with the burrowing behaviors of cicadas, a brief summary is given here (abstracted from Werner and Olson 1994:41):

> Cicada nymphs [larval stage] spend their entire lives underground, making smooth tunnels that they use to get to the roots of plants, into which they insert their sucking mouth parts. They spend several years underground, molting and growing to nearly adult size. In the year when they will become adult, they burrow up near the surface and spend some weeks there before emerging from the ground.

Vegetation

Plant Associations and Ethnobotanical Analysis

Vegetation on McGregor includes many of the tree, shrub, herb, and grass species typical of the Chihuahuan desert, upland tablelands, and montane highlands (Ammon 1958; Gile et al. 1981; Wyatt 1976). Kenmotsu (1977) compiled a useful overview of McGregor plants, past and present, and which were likely useful to

Native Americans. His study was tripartite and involved: (1) identifying the major vegetation areas of McGregor, with a checklist of species and their distributions; (2) evaluating changes in vegetation over the past 100 years by consulting the Land Survey Records of the 1880s; and (3) examining what plants on McGregor may have been used by Native Americans. His study is remarkably thorough and insightful, is partly based on fieldwork done during July, September, and October 1975, and is worth recapitulating as an extended summary here.

Drawing on the work of Wyatt (1976), Kenmotsu identified five relatively discrete, major vegetation distribution areas as follows:

1. Mesquite-Saltbush-Broom Snakeweed Association (*Prosopis glandulosa*, var. *Torreyana-Atriplex canescens-Xanthocephalum sarotheae*)
   This area occupies the western part of the McGregor Range in the Tularosa Basin Zone, and is typified by a mesquite-saltbush association atop coppice dunes. The low scrub mesquite spreads atop the coppices and stabilizes them, with its adventious roots intimately involved in the stabilization process. Kenmotsu noted that the interdune vegetation is predominantly broom snakeweed, sand sage (*Artemisia filifolia*) and soaptree yucca (*Yucca elata*).

2. Creosotebush-Tarbush Association (*Larrea tridentata-Flourensia cernua*)
   On the sand, silt, and gravel of the alluvial fans along the Jarilla Bolson and Broken Escarpment Zones of McGregor, the creosotebush-tarbush Desert Scrub association predominates. According to Kenmotsu, creosotebush may also be co-dominant with whitethorn acacia (*Acacia constricta*), bush muhly (*Muhlenbergia Porteri*), or broom snakeweed in local areas of the fans. Less important though often present plants are ocotillo (*Fouquieria splendens*), mariola parthenium (*Parthenium incanum*), Spanish dagger (*Yucca torreyi*), sotol (*Dasylirion* sp.), and various cacti.

3. Grassland
   Primarily in the Otero Mesa Zone, a rolling to level grassland association is present that consists predominantly of gramas (*Bouteloua* spp.), dropseeds (*Sporobolus* spp.), and vine mesquite (*Panicum obtusum*). The grassland is joined here and there by occasional shrub patches and by riparian communities.

4. Sotol-Ocotillo-Agave Mixed Scrub Association (*Dasylirion wheeleri-Fouquieria splendens-Agave* spp.).
   This association also occurs along the Broken Escarpment Zone on pediments and in foothills of the mountains. Slope, drainage, aspect, and other factors, Kenmotsu notes, play key roles in creating mosaics of xeric habitats, which leads to greater floral diversity in the area. Slopes and pediments have scattered ocotillo, sotol, tree cholla (*Opuntia imbricata*), and, in the Hueco Mountain area, *Agave lecheguilla*. Along streams such species as desert willow (*Chilopsis linearis*), splitleaf brickellbush (*Brickellia laciniata*), and apache plume (*Fallugia paradoxa*) are common.

5. Pinyon Pine-Juniper Association (*Pinus edulis-Juniperus monosperma*)
   This association occurs in the Sacramento Mountains Zone where elevation and aspect are major factors in determining plant distributions. According to Kenmotsu, xeric species predominate below 6,000 ft. On slopes, this zone includes yucca, broom snakeweed, ocotillo, cacti, sotol, with Parry agave fringing the mountain ridges. On more moist slopes, grasses, particularly side-oats grama (*Bouteloua curtipendula*), may co-dominate with this association. Above 6,000 ft, to and beyond the McGregor Range boundary, Kenmotsu recorded xeric species, grasses, piñon, and one-seeded juniper, a mix which represents the lower limit of the "dense pinyon-juniper zone that lies outside the range perimeter" (Kenmotsu 1977:56).

Kenmotsu statistically analyzed the vegetation by sample plots using both the transect and line-intercept methods (commonly employed by botanists). He arrayed these data in numerous tables, and in other tables

arrayed all the species he recorded by distribution area, and by ethnobotanical probable use. He included in his tables species observed on McGregor Range or near it by Wyatt (1976) and by M. L. Butterwick (unpublished survey, ca. 1977). The significance of the latter is that there were a great many species of plants on McGregor that aboriginal people probably used for food, medicines, spiritual purposes, and so on. If more specific information is needed, Kenmotsu's tables should be consulted.

Changes in Vegetation Over the Last 100 Years

One of the most useful aspects of Kenmotsu's work as it relates to this report is his section on vegetation changes over the past 100 years. By examining records of the New Mexico Territorial Land Surveys, Kenmotsu (1977) compared observations on vegetation in two McGregor areas that were made in 1884 with that present in the mid-1970s when his study was done. One area was around and north of the McGregor Base Camp, the other was east of Orogrande in the Jarilla Bolson. Here it is important to note that the five-year period 1880-1885 was exceptionally moist (see Appendix C), and it coincided with the early settlement period of the Tularosa Basin. The reputation of the whole region as prime grazing land was then becoming widespread, which attracted many settlers from the east who wanted to make their fortunes on this grazing largess. Prior to this time the area had been off limits to settlers because of hostile Mescalero Apache activity (Faunce n.d; Freeman 1977, 1981; Sanders 1982). Rather than paraphrase Kenmotsu's analysis of the land survey records, it is more instructive to quote him directly (Kenmotsu 1977:39):

> Presently [mid-1970s], the vegetation of the study area is diverse, varying from a mesa grassland formation, a complex of xeric species and a savanna-like pinyon-juniper zone in the montane regions, and a desert scrub dominance on the basin lowlands. Similar to other parts of southern New Mexico, the flora of the basin portion of McGregor has formed in a *Prosopis* (mesquite) dune field on the lower valley areas and a *Larrea-Flourensia* (creosote bush-tarbush) association on the gravelly alluvial fans (Wyatt 1976:8).
>
> The wide-spread occurrence of these plant associations in other areas of southern New Mexico and the study of climax conditions prior to the establishment of the associations have attracted the interest of a number of investigators (Buffington and Herbel 1965; Gardner 1951; York and Dick-Peddie 1969). The findings of these studies generally indicate a great reduction in the areal cover of grama grass (*Bouteloua* sp.) and an expansion in the population of woody species, primarily creosotebush, mesquite, and juniper during the past hundred years. Intensive grazing of domestic livestock is considered the causative factor for this shift.
>
> While it may be generally assumed that this pattern of vegetation change is consistent throughout much of southern New Mexico, little information directly related to the [McGregor] range area is available in previous writings. In an attempt to verify the fact of these vegetation changes within the study area, this research was focused, in part, toward developing a preliminary interpretation of the nature of these changes and a partial reconstruction of the vegetation pattern shifts that have taken place on the McGregor Range during the past hundred years.

The land surveyors task was to evaluate the land in terms of its agriculture potential, which was done by noting the dominant vegetation forms along the survey lines of every township accompanied by a short summary of the entire township. Kenmotsu (1977:42) states that:

> While it was not possible to examine the records for each line of all sections within a township, information gleaned from the township boundary surveys and the township summaries provides preliminary evidence for the presence of a radically different vegetation type during the late 1880s. The presence of a luxuriant grassland, which from previous studies was assumed to have occurred, is verified by the survey records as having been established on the McGregor Range area. Moreover, a number

of unexpected shrub forms are reported to have occurred in scattered to dense populations. As is graphically illustrated . . ., the current vegetation pattern of mesquite dune field and creosotebush-tarbush dominance in the basin was preceded by a mosaic of relatively pure grassland and mixed populations of oak, mesquite, and juniper.

Kenmotsu's study shows how drastically the vegetation has changed (Figures 10 and 11). Kenmotsu (1977:43-44) presents six sample excerpts from the 1884 township summaries that are indicative of the descriptions used in his reconstructions of the presettlement vegetation patterns in the two McGregor areas noted (McGregor Base Camp and Jarilla Bolson areas). So that the reader can evaluate them, they are given here (surveyors' names and survey dates are included; Kenmotsu 1977:43-44):

a. Township 22 South, Range 9 East, S. R. Biggs; March 1884
The land is generally rolling to broken. Soil is usually sandy and produces a fine growth of grass which is occasionally cut for hay. A dense growth of mesquite, scrub cedar [juniper], and oak covers a large portion of the township.

b. Township 22 South, Range 10 East, S. R. Biggs; March 1884
Land in eastern portion of the township is mountainous. The western portion is much smoother and is generally covered with a dense growth of scrub oak. Grass in some instances is very fine and grows in great abundance.

c. Township 23 South, Range 9 East, S. R. Biggs; February 1884
[Soil is] generally of sandy nature and produces a fine crop of grass. [The township is] best adapted to grazing purposes, with grasses sufficiently good for hay in places.

d. Township 23 South, Range 10 East, S. R. Biggs; March 1884
Soil is sandy and grass is first rate, well suited to grazing. Portions of township are covered with a dense undergrowth of mesquite, cedar [juniper], and scrub oak.

e. Township 24 South, Range 8 East, L. M. Lampton; January-February 1884
The land is generally level and is covered with a fine growth of grass. Quite dense growths of mesquite, scrub oak, and juniper are found in places.

f. Township 25 South, Range 8 East, L. M. Lampton; January 1884
Generally sandy and covered with a fine growth of grass. Soil is quite good and with water could be made productive. Excellently adapted to grazing, being of a gently rolling nature and producing excellent grasses. Generally covered with a scattered growth of mesquite and oak brush.

Kenmotsu then reviewed survey records made 31, 33, and 40 years later in 1915, 1917, and 1924 in adjacent townships to those surveyed above in the 1880s. No mention of oak or juniper is made, and there is an obvious diminished importance of grasses. In fact, the major shrub dominants that exist today were also noted in the 1915-1924 surveys, leading Kenmotsu to conclude that with few exceptions the later observations were descriptive of the present vegetation of McGregor. What is more, in the later surveys frequent reference is made to "dunes," "sand dunes," "sand hummocks," and "sand hills," expressions that were lacking in the 1884 surveys (though references to "sandy soil" were occasionally made). Kenmotsu notes that these findings are consistent with those of other studies done in other areas of southern New Mexico (Buffington and Herbal 1965; York and Dick-Peddie 1969). They are also consistent with observations made in 1911, four years prior to the onset of the 1915-1924 land surveys, by Meinzer and Hare (1915:46):

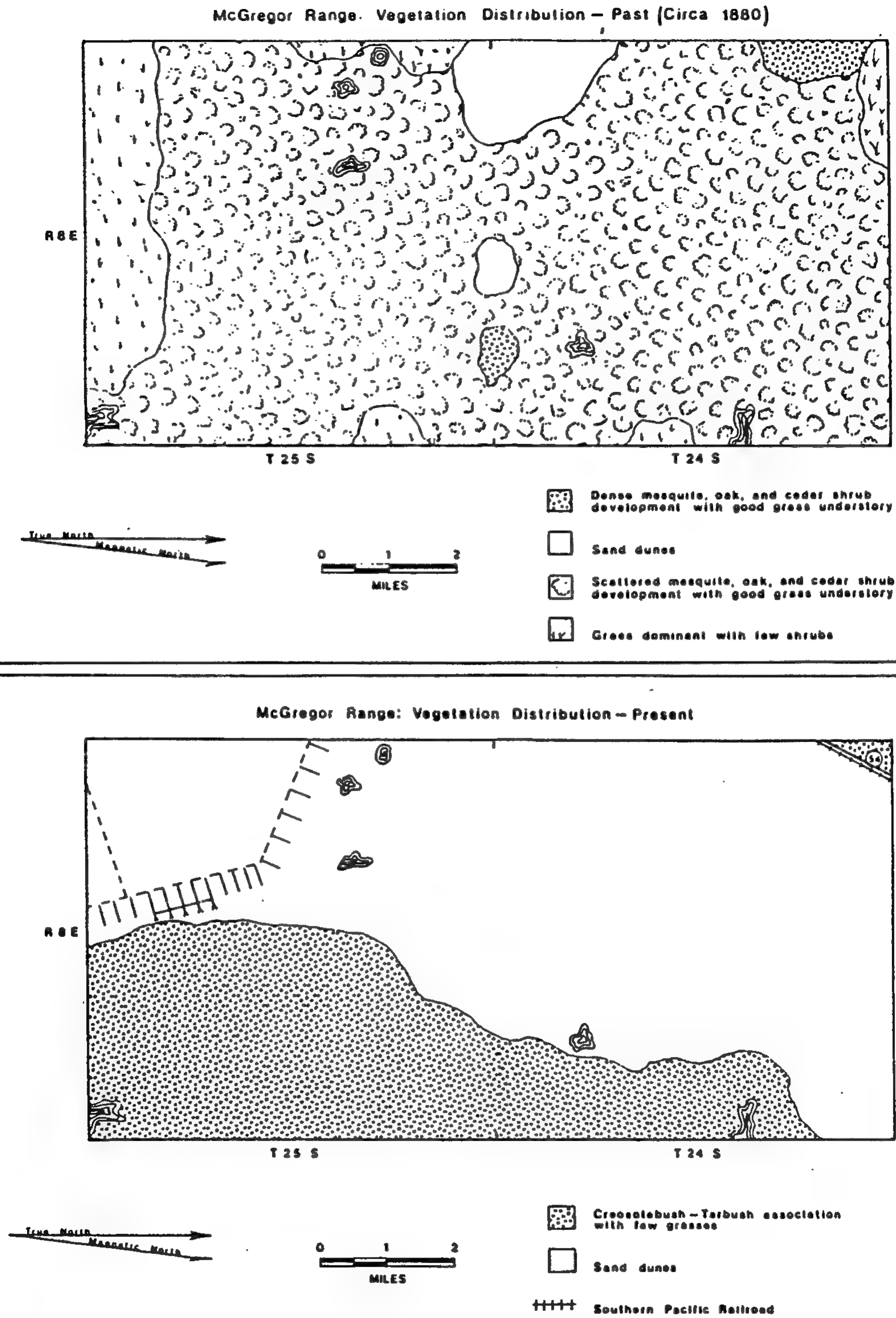


Figure 10. Changes in McGregor vegetation in the Three Buttes area near McGregor Range Camp as recorded in 1880s land surveys (upper figure), as compared to present vegetation (lower figure). The area experienced its most drastic change between 1885 and 1901 when dense to scattered mesquite, oak, and cedar shrub with a grass understory, open grassland, and a few dunes gave way to the present landscape of creosotebush-tarbush association where dunes are dominant (after Kenmotsu 1977).

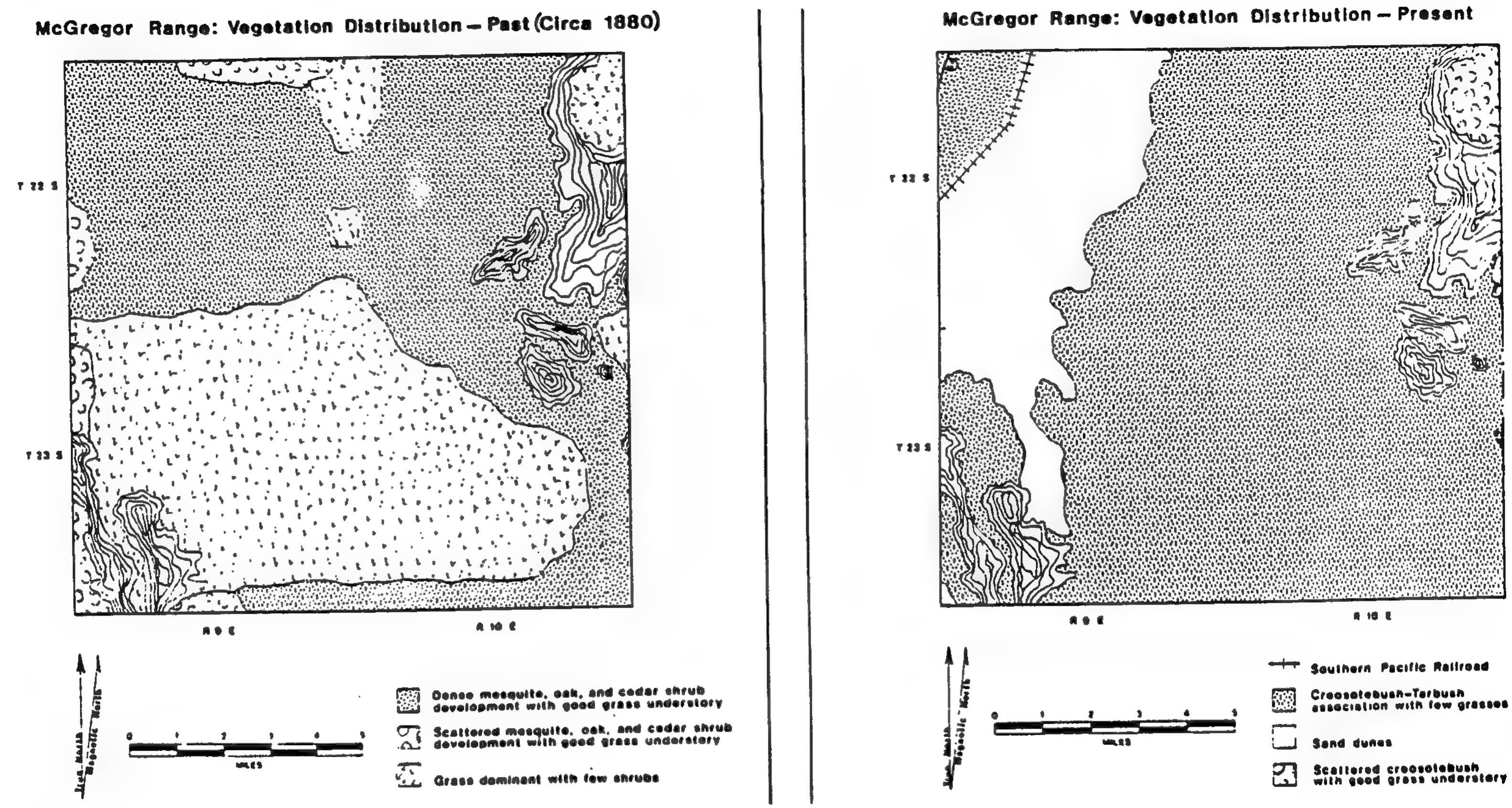


Figure 11. Changes in McGregor vegetation in the Benton Well/Rough Canyon/Hay Meadow Tank/Sulphur Tank areas as recorded in the 1880s land surveys compared to present: Left is vegetation circa 1880, right is vegetation at present. The data show a fundamental and drastic change from dense to scattered mesquite, oak, and cedar shrub with a grass understory and open grassland in the 1880s, to a creosotebush-tarbush association with few grasses, and sand dunes at present (after Kenmotsu 1977).

Low sand dunes of a . . . reddish hue are found over a wide area in the southern part of the [Tularosa] basin. They extend a number of miles north, west, and east of the Jarilla Mountains and south to the Texas line. [Such terms as 'coppice dunes' and 'coppice mounds' did not then exist.]

Kenmotsu concludes that an absence of creosotebush and dune fields in the 1880s, compared with the seeming ubiquity of scrub oak and juniper, describes a McGregor landscape totally unlike what we see today, with clear presettlement ecological implications.

. . . the implication is inescapable that flóral composition and, subsequently, floral resources, during the era of aboriginal occupation greatly contrasted with the composition and distribution patterns of the contemporary flora [Kenmotsu 1977:47].

Meinzer and Hare (1915:21) also noted during this early period that:

[i]n 1911 the amount of range stock was small in comparison with the area of the grazing lands, and a number of the old ranches were abandoned. It appears that the range had been overstocked and that a series of dry years preceding 1911 [1886-1901] caused a serious shortage in the food supply and resulted in a general retrenchment in the ranching business.

In light of the historic wet-dry precipitation pattern of the Tularosa Basin, a pattern of heavy stocking of grazing animals during wet years followed by overgrazing and soil destabilization during dry periods would be expected during the early settlement period. The pattern would have been an understandable precondition of learning the environmental limits to grazing and land use in a drought-prone region of undependable rainfall. The keystone boom and bust period for McGregor which had drastic ecological consequences were the five exceptionally wet years of 1880-1884 (boom) and the subsequent 16 consecutive dry years of 1886-1901 (bust). This pattern typified much of the Southwest during the 22-year period of 1880-1901. A threshold was crossed as the grass was aggressively consumed after 1885 when rainfall decreased. Sandy topsoils became mobile followed by abandonment of many ranches and grazing enterprises. But probably there was no way that early settlers, who were newcomers to this drought-prone environment, could have anticipated the consequences of overgrazing until it was too late.

Long-range ecological research conducted at the Jornada Experimental Station in the Jornada del Muerta area (Schlesinger et al. 1990, 1996) suggests that the 22-year (1885-1901) change from grassland to dominantly shrubland in the Tularosa Basin is probably irreversible, at least in the foreseeable future. This prediction is an outgrowth of the "Jornada Model" by Schlessinger et al. (1990, 1996), where the 1880-1901 overgrazing and rainfall record apparently mirrored those conditions on McGregor. According to the model, nutrient distributions undergo fundamental spatial changes when a grassland becomes a shrubland. Under a grassland, nutrients are typically uniformly distributed, but under shrubland they become point-centered. Creosotebush and mesquite are the main nutrient point centers, and became so during the 1886-1901 period. Once this pattern was established it became biologically self-enhancing, for as rodents, termites, and reptiles took up residence under the shrubs, and in the coppice mounds that formed in the shrubs, their foraging behavior and waste eliminations enhanced the nutrient point-centering process. Further, as sandy coppices formed around shrubs, wind-borne organics such as pollen, leaves, and feces were trapped, further augmenting the nutrient point-centering process. The coppiced shrubs thus became "islands of fertility" for nitrogen and phosphorus, the two nutrients that are most limiting to plant growth in desert soils. Zimmer (1995) has summarized the process. The irreversibility part of the model is that grasses are outcompeted by creosote and mesquite inasmuch as nutrients are point-centered under shrubs, and they cannot thus reestablish themselves.

As a floral footnote to Kenmotsu's study, several junipers were observed by the writer on north-facing slopes opposite the defunct reservoirs in Grapevine Canyon. Several junipers were also observed in the vicinity of Cerro Alto in the Huecos, and Mr. Pete Atkins (personal communication 1996) confirmed their presence in the area. According to Mr. Charlie Lee (personal communication 1996), cottonwood is present on Alamo

Mountain, westernmost of the Cornudas Mountains on Otero Mesa and junipers were historically so common in the upland that a cable system was once set up to harvest them for fence posts. Kenmotsu suggested that harvesting of basin woody species like juniper and oak for fuelwood and building purposes may have hastened their demise. Further, for what it is worth, Mr. Bill McNew, III, recalls as a child (1930s) playing on cottonwood stumps at North Tank on the north side of the Jarillas. (It would be interesting to learn if cottonwood or other arboreal species are mentioned in the land survey records held in Santa Fe.) McNew, who lived for many years on the McNew Ranch in the Jarillas near the mouth of Water Canyon, left New Mexico in 1956. When he returned in 1996 after an absence of 41 years, he was surprised to see how the eastern slopes of the Jarillas are now dominated by creosotebush, whereas in 1956 grama grass covered the area. It was an area his family's cattle used to graze (Bill McNew, III, personal communication 1997).

As a final floral footnote, desert willow is a common tree-shrub along the Sacramento drainage, and cottonwood, salt cedar, and other phreatophytes, both introduced and native, are found at some of the tanks scattered across the McGregor reservation. Salt cedar, a nonnative exotic species is, of course, present at the aptly named Salt Cedar Playa in the Jarilla Bolson. Russian thistle (*Salsola kali*), or tumbleweed, is also a common exotic (introduced) species.

On the gypsiferous alkali flats of far northwestern McGregor Range, the vegetation is sparse, but the small gray Tiquilia plant (*Tiquilia gossypina*) is common and has adapted well to the alkaligypsum-rich environment. Also adapted to this alkaline terrain, though obviously not as well because they are fewer in number, are creosotebush and yucca. All three forms are present on some gypsite-rich playa lunettes, for example at Cox Playa, Salt Cedar Playa, and Lone Butte Playa.

By far and away the most conspicuous present shrub species in the Tularosa Basin part of the reservation, as indicated in Kenmotsu's study, are honey mesquite and creosotebush. Mesquite is the principal anchoring species for coppice dunes, with creosotebush greatly subsidiary in rank. Kenmotsu's study, Meinzer and Hare's 1911 observations, as well as the nineteenth century observations by others cited in Freeman (1977), Zimmer (1995), and Meinzer and Hare (1911), and the oral traditions of pioneer family descendants (various communications during this study) confirm that the coppiced shrublands are largely of historic origin and the result of overstocking and overgrazing during the 22-year 1880-1901 wet-dry period. As the story goes, too many cattle overgrazed the grass and trampled the sandy soil, plus ate mesquite beans from parent shrubs that then grew along washes and in clumps. As wind eroded the trampled soil cattle spread mesquite seeds across the disturbed landscape wherever they grazed. Upon germination, coppicing began around the bases of the young mesquites. That sand sheets and sandy soils were present in prehistoric time in the southern Tularosa Basin, however, is confirmed by evidence presented in later sections of this report.

Soils

Soils on McGregor have been mapped by Derr (1981), and were studied as part of a McGregor geological reconnaissance by Pigott (1977). Figure 12 is a very general soil association map for all of Otero County and several adjoining areas, and includes the McGregor Range. Mapping units 3-6, 7, and 10-13 on this map are the ones present on McGregor (unit 3, while not shown as present on McGregor, is present in the northwestern part of the Range). Figure 13 is a more detailed, though still general, raster map showing 31 soil associations based on soil maps in Derr (1981). Formal descriptions of most of these soils are in Appendix C. As of this writing the NRCS (formerly Soil Conservation Service) is remapping the soils of McGregor (Hays Dye, personal communication 1997).

Most of McGregor's soils are either Aridisols or Entisols, with a few Mollisols in certain mountain grassy areas, and an occasional Vertisol (four Orders total). Suborders represented on McGregor are Argids (few to common), Orthids (very many), Orthents and Psamments (very many), Ustolls (few), and Usterts (very few). Argids are common on the La Mesa surface (Doña Ana soils), with some on Jarilla alluvial fans, and

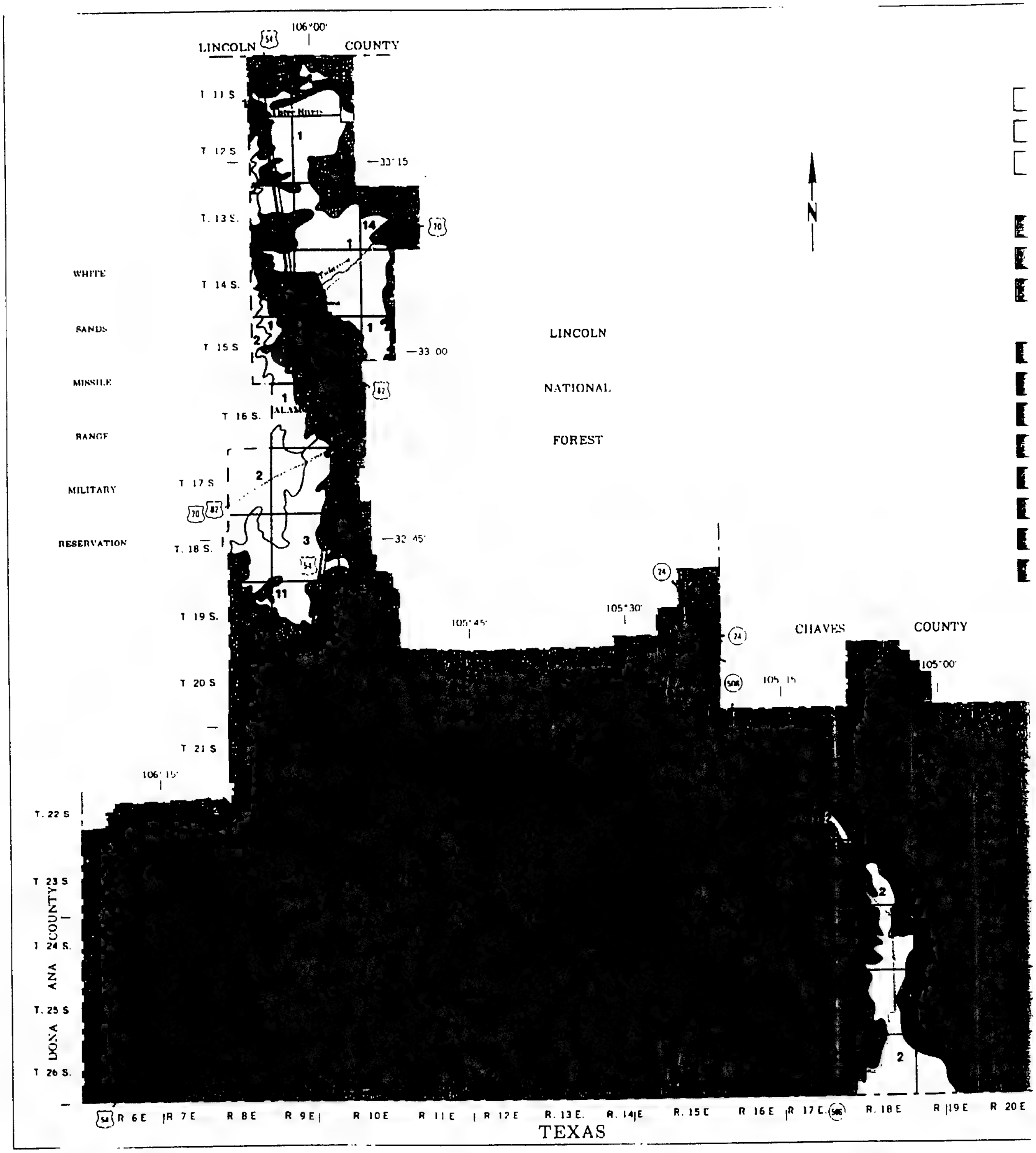
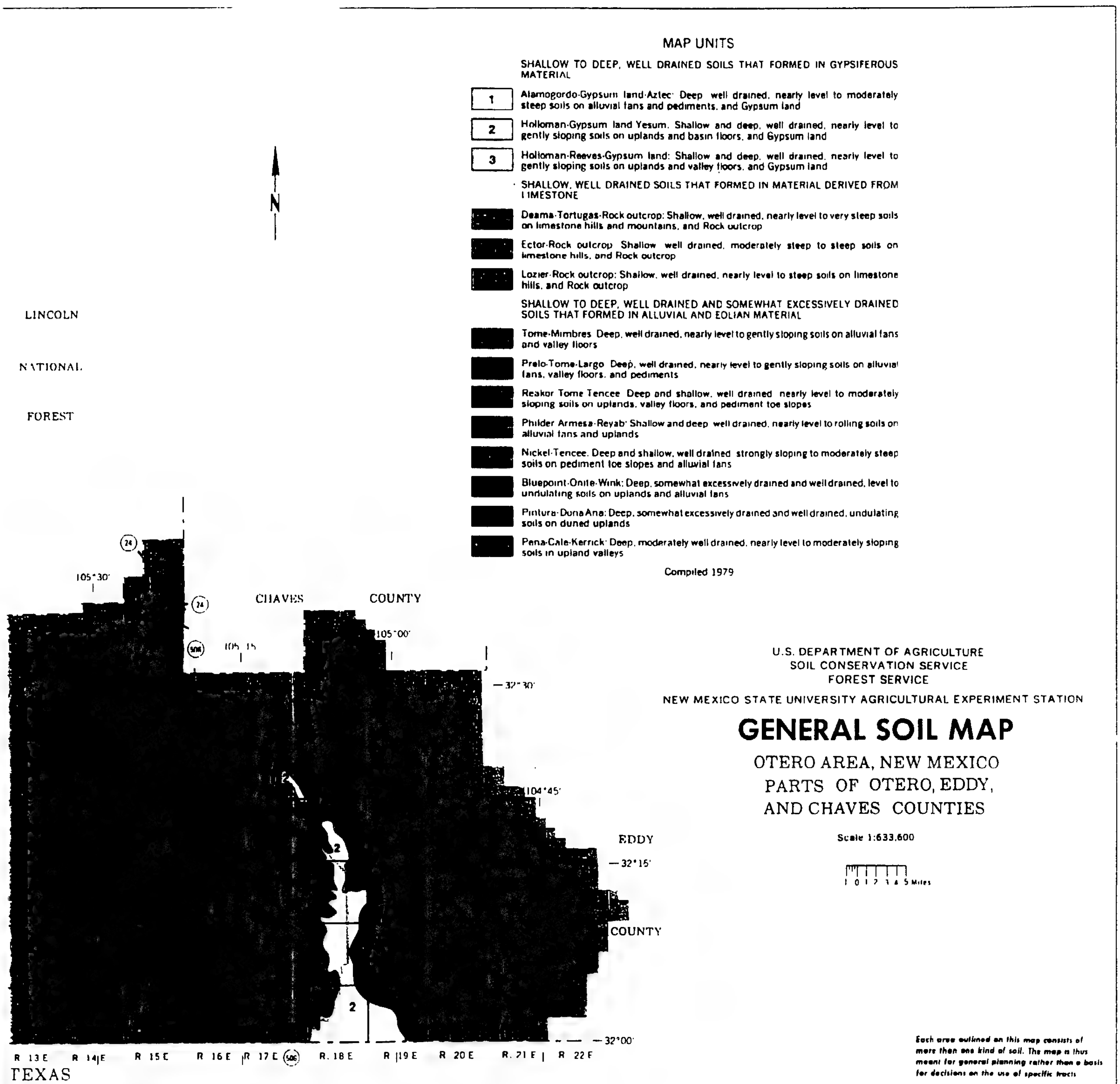


Figure 12. General soil map of the Otero area, New Mexico, and parts of Otero, Eddy, and Chaves counties (from Derr 1981).

1



Eddy, and Chaves counties (from Derr 1981).

MAP UNITS

TO DEEP, WELL DRAINED SOILS THAT FORMED IN GYPSIFEROUS

›-Gypsum land-Aztec: Deep well drained, nearly level to moderately
›n alluvial fans and pediments, and Gypsum land

·ypsum land Yesum. Shallow and deep, well drained, nearly level to
ng soils on uplands and basin floors, and Gypsum land

eeves-Gypsum land: Shallow and deep, well drained, nearly level to
ng soils on uplands and valley floors, and Gypsum land

WELL DRAINED SOILS THAT FORMED IN MATERIAL DERIVED FROM

ugas-Rock outcrop. Shallow, well drained, nearly level to very steep soils
ı hills and mountains, and Rock outcrop

outcrop: Shallow, well drained, moderately steep to steep soils on
lls, and Rock outcrop

outcrop: Shallow, well drained, nearly level to steep soils on limestone
ck outcrop

O DEEP, WELL DRAINED AND SOMEWHAT EXCESSIVELY DRAINED
FORMED IN ALLUVIAL AND EOLIAN MATERIAL

'es Deep, well drained, nearly level to gently sloping soils on alluvial fans
oors

.argo. Deep, well drained, nearly level to gently sloping soils on alluvial
'loors, and pediments

: Tencee Deep and shallow, well drained, nearly level to moderately
on uplands, valley floors, and pediment toe slopes

:sa Reyab: Shallow and deep, well drained, nearly level to rolling soils on
and uplands

·e Deep and shallow, well drained, strongly sloping to moderately steep
ment toe slopes and alluvial fans

ıite Wink: Deep somewhat excessively drained and well drained, level to
oils on uplands and alluvial fans

ı Ana. Deep, somewhat excessively drained and well drained, undulating
:d uplands

·rrick Deep, moderately well drained, nearly level to moderately sloping
ıd valleys

Compiled 1979

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
FOREST SERVICE

NEW MEXICO STATE UNIVERSITY AGRICULTURAL EXPERIMENT STATION

GENERAL SOIL MAP

OTERO AREA, NEW MEXICO
PARTS OF OTERO, EDDY, AND CHAVES COUNTIES

Scale 1:633,600

1 0 1 2 3 4 5 Miles

Each area outlined on this map consists of more than one kind of soil. The map is thus meant for general planning rather than a basis for decisions on the use of specific tracts.

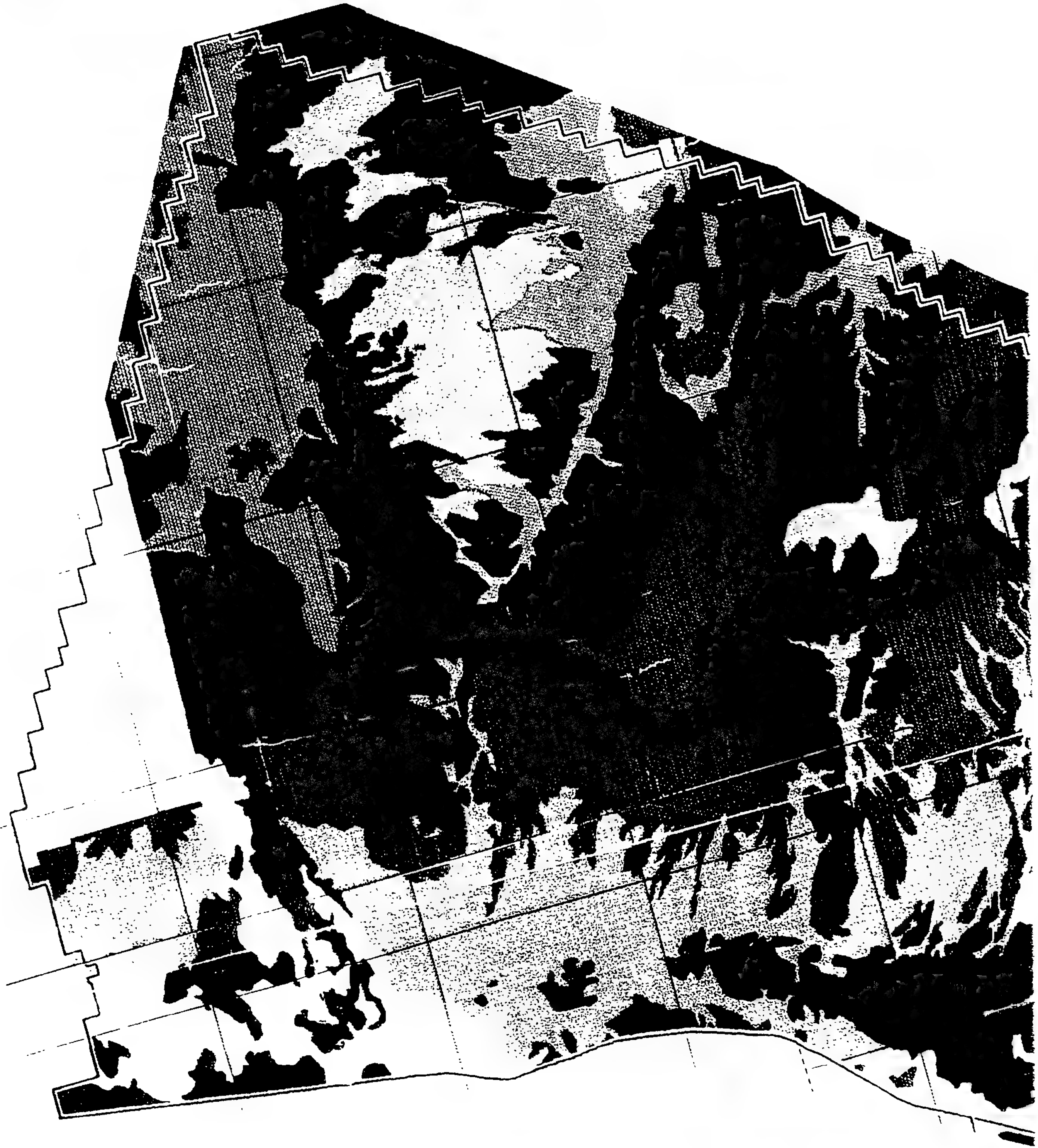
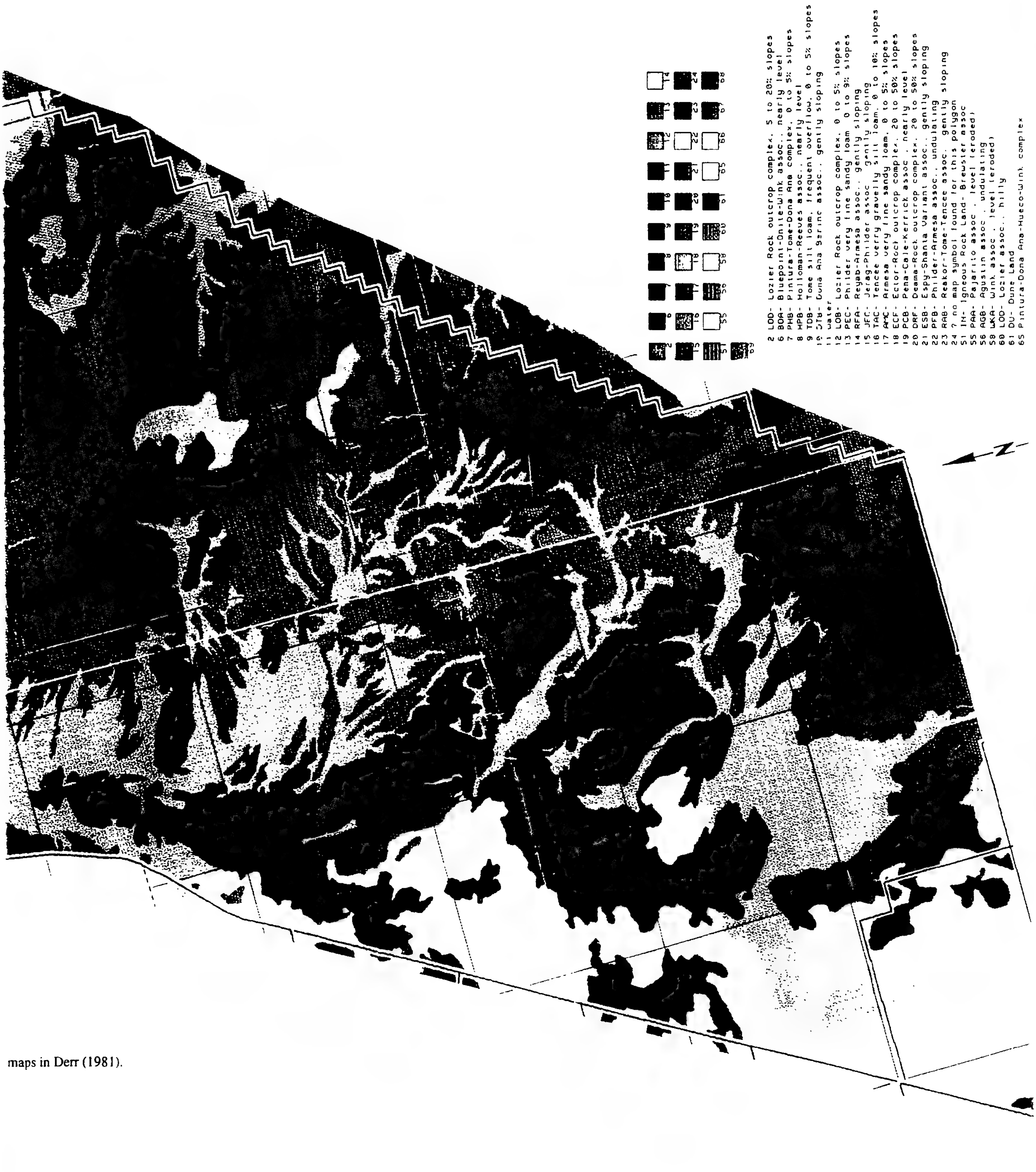
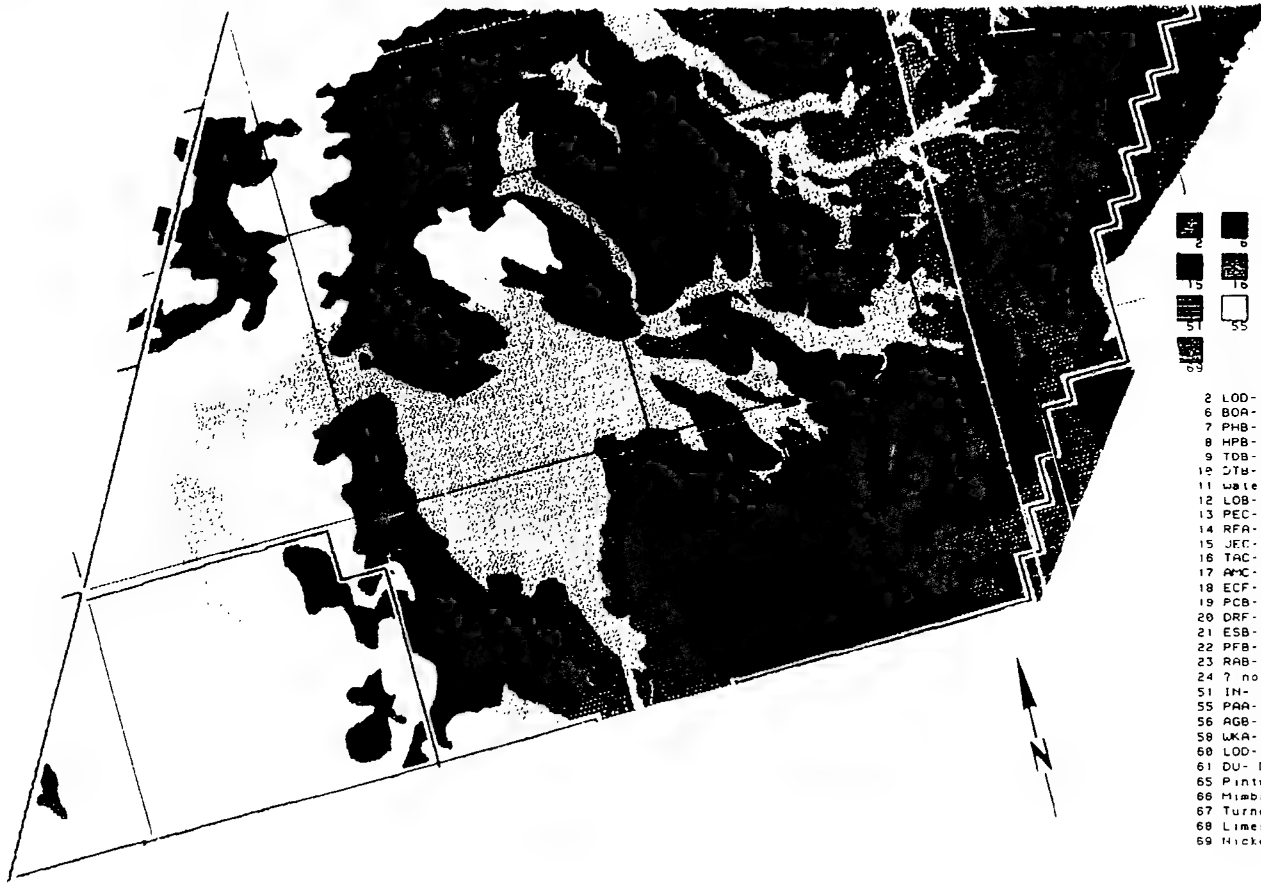


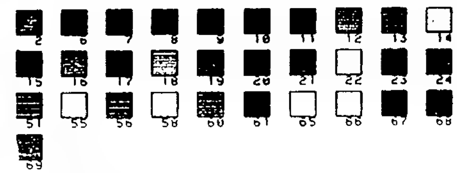
Figure 13. Generalized raster map showing 31 soil associations for McGregor, based on soil maps in Derr (1981).

(1)



maps in Derr (1981).




2 6 7 8 9 10 11 12 13 14
15 16 17 18 19 20 21 22 23 24
51 55 56 58 60 61 65 66 67 68
69
2 LOD- Lozier Rock outcrop complex, 5 to 20% slopes
6 BOA- Bluepoint-Onite-Wink assoc., nearly level
7 PHB- Pintura-Tome-Dona Ana complex, 0 to 5% slopes
8 HPB- Holloman-Reeves assoc , nearly level
9 TDB- Tome silt loam, frequent overflow, 0 to 5% slopes
10 DTB- Dona Ana Berino assoc., gently sloping
11 water
12 LOB- Lozier Rock outcrop complex, 0 to 5% slopes
13 PEC- Philder very fine sandy loam, 0 to 9% slopes
14 RFA- Reyab-Armesa assoc., gently sloping
15 JEC- Jerag-Philder assoc. gently sloping
16 TAC- Tencee verry gravelly silt loam 0 to 10% slopes
17 AMC- Armesa very fine sandy loam, 0 to 5% slopes
18 ECF- Ector-Rock outcrop complex, 20 to 50% slopes
19 PCB- Pena-Cale-Kerrick assoc., nearly level
20 DRF- Deama-Rock outcrop complex, 20 to 50% slopes
21 ESB- Espy-Shanta Variant assoc., gently sloping
22 PFB- Philder-Armesa assoc., undulating
23 RAB- Reakor-Tome-Tencee assoc., gently sloping
24 ? no map symbol found for this polygon
51 IN- Igneous Rock Land- Brewster assoc.
55 PAA- Pajarito assoc., level (eroded)
56 AGB- Agustin assoc., undulating
58 WKA- Wink assoc , level (eroded)
60 LOD- Lozier assoc., hilly
61 DU- Dune Land
65 Pintura-Dona Ana-Hueco-Wink complex
66 Mimbres-Tome complex
67 Turney-Berino-Dona Ana complex
68 Limestone Rockland- Lozier complex
69 Nickel-Tencee-Simona complex

3

on old dunes (Berino soils) around the Jarillas and in the Jarilla Bolson. Orthids and Orthents dominate the limestone bedrock, pediments, and lime-rich alluvium in the Broken Escarpment-Hueco Mountains and Otero Mesa zones, and some occur in the basin. Psamments dominate the coppiced dunelands of the Tularosa Basin (Pintura Soils) and the individual dunes of Otero Mesa, and Ustolls occur patchily in the Sacramento Mountains. Usterts occur on several playas (e.g., Vertisol Playa). Table 2 lists the soil series on McGregor and their taxonomic status.

Figure 14 shows three soil-landform models produced in Derr (1981) that are relevant to the McGregor Range inasmuch as the series represented occur on the reservation. More detailed assessments of soils and soil forming processes, factors and conditions (soil genesis) is presented below in the Geomorphology and Soils section on a site-specific basis, augmented by descriptions in Appendix D.

In a geological reconnaissance of McGregor, Pigott (1977:Figure III-12) produced a general soil map based on photointerpretation of NASA Apollo space photographs plus some fieldwork. However, the more detailed later study by Derr (1981) supersedes Pigott's effort, so his map is not included here. Pigott also produced a soil associations map for the prehistoric period A.D. 800-600, but inasmuch as the criteria used for it seem uncertain, at least to this writer, it too was not included here.

Dunes

Sand dunes on the McGregor Range dominate the Tularosa Basin and sparsely occur on Otero Mesa. The ultimate source of dune sands on the McGregor Range and Tularosa Basin are Paleozoic redbeds, many of which are paleosols. They derive mainly from the reddish Abo and Yeso formations of Permian age, and the reddish Bliss Sandstone of Cambrian-Ordovician age. They locally outcrop here and there in the surrounding uplands, including the Sacramento Mountains-Otero Escarpment-Hueco Mountains, the Franklin-Organ-San Andres mountains, and the westernmost of the Tres Hermanos Buttes (Twin Buttes). Conspicuous Permian redbeds outcrop for several miles all along the lower midslopes of the Otero Escarpment east of Jarilla Bolson, from Rough Canyon north to County Road 506. Red silt and sand weathered from the outcrops are visible in washes that drain west from the area. In fact, the entire area downslope of the redbeds, from the Otero Escarpment west to the old McGregor (Fleck's Home) Ranch north to and beyond Wilde Well, has a pinkish hue. Reddish sands eroded from these rocks can be observed in transit in many small washes draining into El Paso Draw from both the Sacramento Mountains and Otero Escarpment. Fieldwork confirmed these redbed source areas, and it is clear that enormous quantities have washed into the Tularosa Basin during the Tertiary and Quaternary. The process is active today as a visit to any redbed outcrop will attest. It is worth emphasizing that the reddish color of the Tularosa Basin sands is due to pedogenic weathering originally and primarily in Paleozoic soils, augmented by pedogenetic iron oxide overprints in modern soils.

A secondary source of the sands, and its main expressions as mobile dune sheets, dune piles and dune trains, is widespread historic erosion of the La Mesa topsoils (A horizons). As indicated, erosion began in the mid-1880s due to livestock pressure, its main pulse being felt between 1885 and 1901. Eolian erosion has apparently continued from then until now, with probably a secondary pulse after the military acquired the area and vehicular maneuvers began. The historically mobilized sand has been informally referred to as the Newman Sand by Pigott (1977). According to Pigott, nearly 18 percent of McGregor Range is veneered with Newman Sand, and this would include nearly all of the Tularosa Basin Zone. Eolian sand dominates the Tularosa Basin Zone and impacts certain parts of the Broken Escarpment-Hueco Mountains Zone, especially certain limestone outliers like the Hueco Bedrock Finger area. Some sand has saltated up onto Otero Mesa, forming isolated local dunes scattered here and there across the tableland (e.g., at Camaleche Tanks). As indicated in Chapter 1, dunes are classified and mapped in this report as local dunes, dune piles, dune sheets (uncoppiced, coppiced), and playa lunette dunes (cf., Melton 1940).

Table 2
Classification of Soils
(adapted from USDA, Soil Survey of Otero Area, New Mexico:Table 26, 244)

Soil name	Family or higher taxonomic class
Alamogordo	Coarse-loamy, gypsic, thermic Typic Gypsiorthids
Alamogordo Variant	Fine-loamy, mixed, thermic Cambic Gypsiorthids
Armesa	Fine-loamy, carbonatic, thermic Ustollic Calciorthids
Aztec	Loamy-skeletal, mixed, thermic Cambic Gypsiorthids
Aztec Variant	Loamy-skeletal, mixed, mesic Cambic Gypsiorthids
Berino	Fine-loamy, mixed, thermic Typic Haplargids
Bluepoint	Mixed, thermic Typic Torripsamments
Borrego	Clayey, mixed Lithic Eutroboralfs
Cale	Fine-silty, mixed, mesic Aridic Argiustolls
Crowflats	Fine-silty, mixed (calcareous), thermic Ustic Torrifluvents
Deama	Loamy-skeletal, carbonatic, mesic Lithic Calciustolls
Doña Ana	Fine-loamy, mixed, thermic Typic Haplargids
Dye	Clayey, mixed, mesic Lithic Haplustalfs
Ector	Loamy-skeletal, carbonatic, thermic Lithic Calciustolls
Emot	Loamy-skeletal, mixed (calcareous), thermic Typic Torriorthents
Encierro	Clayey, mixed, mesic Lithic Argiustolls
Espy	Loamy, mixed, thermic, shallow Petrocalcic Calciustolls
Gabaldon	Fine-silty, mixed, mesic Cumulic Haplustolls
Holloman	Loamy, gypsic, thermic, shallow Typic Torriorthents
Holloman Variant	Loamy, mixed, mesic, shallow Typic Haplustolls
Jal	Fine-loamy, carbonatic, thermic Typic Calciorthids
Jerag	Loamy, mixed, thermic, shallow Petrocalcic Ustalfic Paleargids
Kerrick	Fine-loamy, mixed, mesic Petrocalcic Calciustolls
La Fonda	Fine-loamy, mixed, mesic Ustollic Camborthids
Largo	Fine-silty, mixed (calcareous), thermic Typic Torriorthents
Lozier	Loamy-skeletal, carbonatic, thermic Lithic Calciorthids
McCullough	Coarse-loamy, mixed (calcareous), thermic Typic Torriorthents
McCullough Variant	Fine-loamy, mixed (calcareous), thermic Typic Torriorthents
Mead	Fine, mixed, thermic Typic Salorthids
Mimbres	Fine-silty, mixed, thermic Typic Camborthids
Montecito	Fine, mixed, mesic Aridic Haplustalfs
Nickel	Loamy-skeletal, mixed, thermic Typic Calciorthids
Ogral	Loamy-skeletal, mixed (calcareous), thermic Typic Torriorthents
Onite	Coarse-loamy, mixed, thermic Typic Haplargids
Pena	Loamy-skeletal, mixed, mesic Aridic Calciustolls
Pena Variant	Loamy-skeletal, mixed, mesic Pachic Haplustolls
Philder	Loamy-skeletal, carbonatic, thermic, shallow Ustochreptic Paleorthids
Pintura	Mixed, thermic Typic-Torripsamments
Prelo	Fine-silty, mixed, thermic Typic Camborthids
Prelo Variant	Fine-loamy, mixed, thermic Typic Camborthids
Reakor	Fine-silty, mixed, thermic Typic Calciorthids
Reeves	Fine-loamy, gypsic, thermic Typic Gypsiorthids
Reeves Variant	Fine-loamy, mixed, mesic Aridic Calciustolls
Reyab	Fine-silty, mixed (calcareous); thermic Ustic Torriorthents
Ruidoso	Fine, mixed, mesic Pachic Argiustolls
Shanta	Fine-loamy, mixed, mesic Cumulic Haplustolls
Shanta Variant	Fine-loamy, mixed, thermic Aridic Haplustolls
Tencee	Loamy-skeletal, carbonatic, thermic, shallow Typic Paleorthids
Tobler	Coarse-loamy, mixed (calcareous), thermic Typic Torrifluvents
Tome	Fine-silty, mixed (calcareous), thermic Typic Torriorthents
Tortugas	Loamy-skeletal, carbonatic, mesic Lithic Haplustolls
Wink	Coarse-loamy, mixed, thermic Typic Calciorthids
Yesum	Coarse-loamy, gypsic, thermic Typic Gypsiorthids

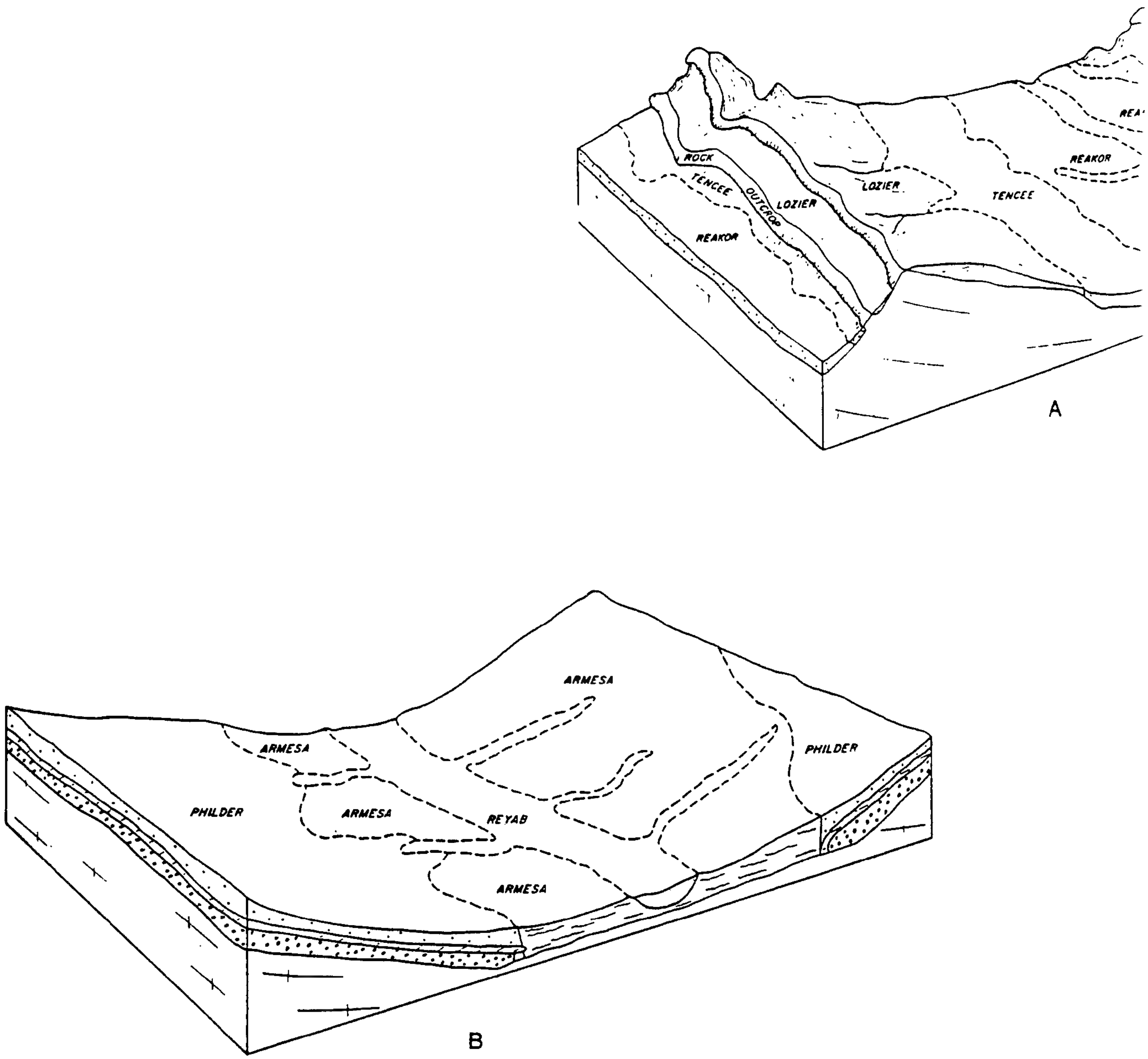
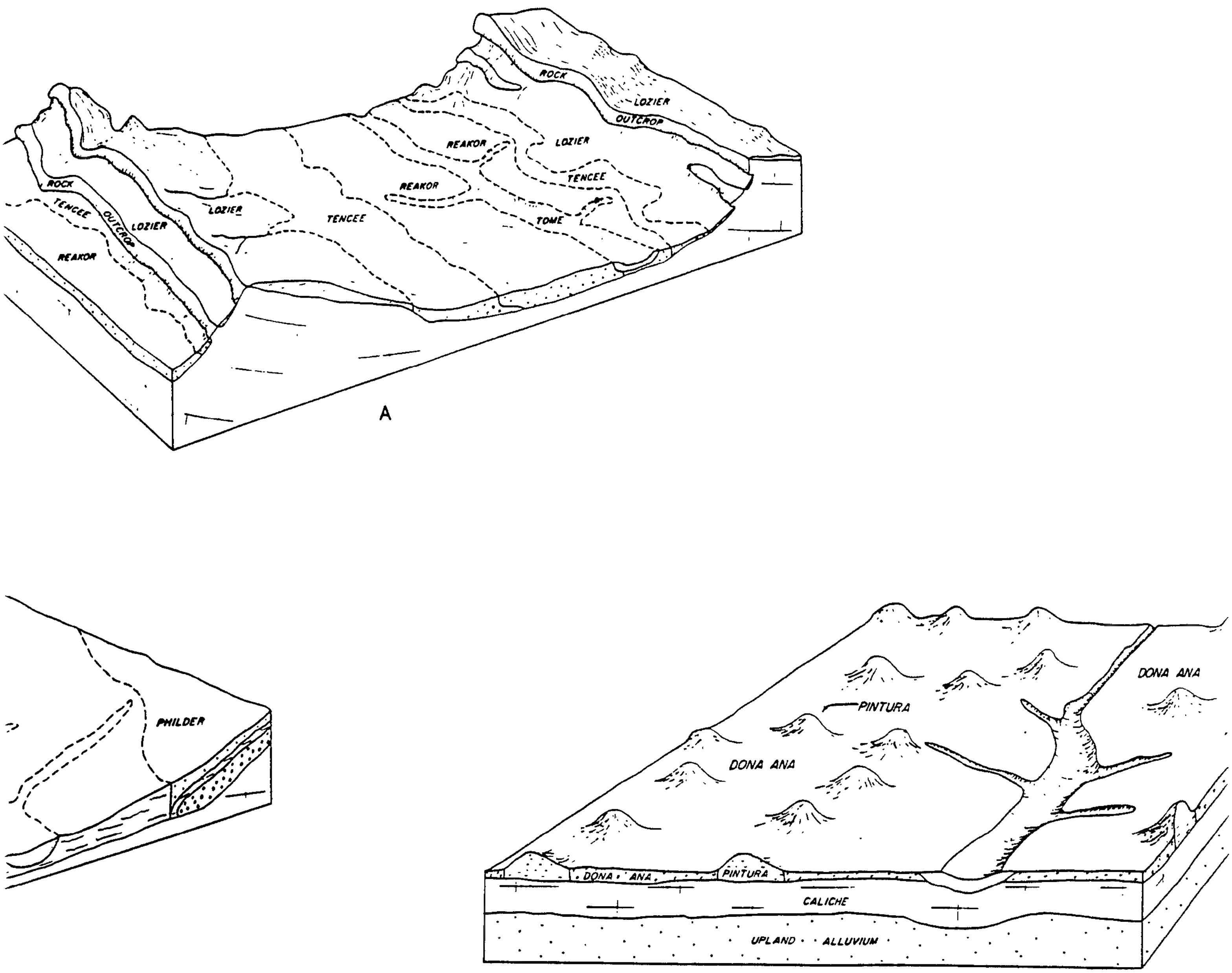
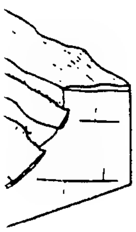


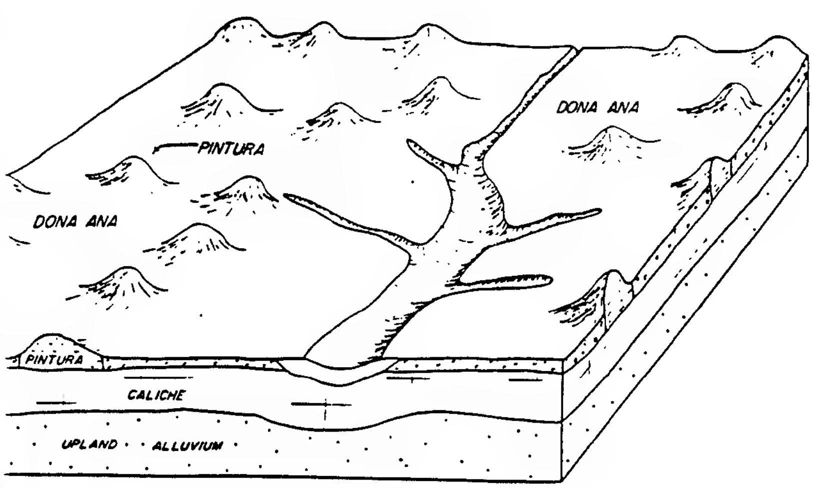
Figure 14. Patterns of soil and landform relationships: (a) in Lozier-Rock outcrop and Reakor-Tome-Tencee map units of Figure 12 (from Derr 1981); (b) i



l Reakor-Tome-Tencee map units of Figure 12 (from Derr 1981); (b) in Philder-Armesa-Reyab map unit; and (c) in Pintura-Doña Ana map unit of Figure 12 (from Derr 1981).

2





C

and (c) in Pintura-Doña Ana map unit of Figure 12 (from Derr 1981).

3

Local Dunes

Local dunes are relatively thin (often a meter or two or less), are localized, and are of limited areal extent. They mainly occur on Otero Mesa—for example, along the lower reaches of El Paso Draw (Otero Mesa North and El Paso Draw quads). Here brownish-reddish dunes cover distal toeslopes of alluvial fans emanating from the Sacramento Mountains and from the higher parts of Otero Mesa to the south. They occur as small dunes along the thalweg of the Draw. Scattered local dunes also are present here and there over Otero Mesa, some having traveled considerable distances downwind to the east. Local dunes are important archeologically because artifacts were (are) observed on almost every local dune encountered along El Paso Draw, some mixed with caliche on badger burrow spoils and apparently cycled up from below.

Dune Piles

Dune piles are thick (many meters) accumulations of sand and/or multiple buried sand sheets, and usually are mobile. They often exhibit lobate geometries on air photos and sometimes show a rippled or mega-rippled appearance, which reflects recent movements and ongoing historic slow transit downwind. Mega-ripples and crescentic lobate forms are particularly common in the sand piles of the Jarilla Bolson and lower midslopes of the Grapevine Canyon fan (Orogrande N-S, Wilde Tank, and Pipeline Canyon quads). shows Such lobate dune trains are marching northeast through the Jarilla Gap, then north across the Jarilla Bolson, and marching from the Moody Lowlands east-northeast onto the Culp and Grapevine Canyon fans, and even up onto the Sacramento Mountain Escarpment (Pipeline and Culp canyons quads; Figures 15 and 16). Figures 17 and 18 show a close-up of active and inactive (moribund) dune trains in the Cox Playa area of the Jarilla Bolson. Dune piles also occur in the Davis Dome area (Desert SE quad).

Some dune piles are shown on air photos as sandy areas with vegetation-free light colored spots, almost whitish in some cases, which are active or formerly active mounds of harvester ants (*Pogonomyrmyx apache* [Wheeler] and *P. rugosa* [Emery]). The ants typically harvest (remove) vegetation from around their mounds and may armor the mounds with sand-sized pieces of whitish caliche bioturbated up from residual subjacent (buried) soil. The mound and surrounding vegetation-free areas are clearly visible on color air photos as ant spots, which exemplify many of the dune piles in and adjacent to the Bolson Floor Complex and along the Lake Tank Fault scarp near Davis Dome. Possibly the presence of ants in thick dune piles reflects their preference for deep sand as habitat. So, ant spots, in addition to ripples and lobate forms, are another diagnostic criterion for dune piles. Vegetation harvesting by ants may keep dune piles destabilized and augment wind deflation and dune migration.

Dune piles and dunes in general are extremely important though complicating elements in the geomorphology of the McGregor Range. Their concentration on the east side of Tularosa Basin, and the strong paleosols formed in the lower parts of some, proves that they have been accumulating for long periods of the late Quaternary (at least) and that the wind pattern has long been mainly SW to NE. In fact, to fully appreciate the rationale behind the Dune Pile (DP) and other dune mapping units (dune sheet [DS] and dune sheet coppiced [DSC]) requires an understanding of the age and origin of the sand in the Tularosa Basin, and the age and origin of the dune piles that form part of the sand. First, as noted, the ultimate sources for Tularosa Basin sands are Paleozoic redbeds in bordering uplands, mainly Bliss Sandstone and Yeso Formation rocks, which doubtless have been shedding sand into the basin for as long as exposures have existed. Indeed, dune sheets and dune piles were accumulating here long before Europeans or Native American ever arrived in North America. When the Rio Grande abandoned the lower Tularosa Basin in mid-Pleistocene times and left Camp Rice river sediments behind, soil began forming in them, and has been forming in them since.

Sediment from upland redbeds made its way onto the margins of this early La Mesa surface via stream wash, and ultimately onto playas.

When basin footslopes and playas dry out after storms, the fluvially deposited sediment is deflated by wind. Dust is blown away, and dunes form from the coarse fraction left behind. The process has occurred repeatedly in many basins and plains of western North America, and occurs in many of these same areas today, including the Tularosa Basin.

Dunes tend to accumulate on basin floors because that is where sediment is ultimately washed, and from which dune sand derives. If unanchored, dunes migrate in the prevailing wind direction, which in the Tularosa Basin is southwest to northeast. Dune sand consequently forms from basin sediments as eolian lag, then migrates downwind—sometimes upslope onto and over escarpments—and piles up on wind struck uplands. It has long done this along the east side of the Tularosa Basin. Its ultimate destination is in downwind areas, either where wind is strongest, as in Culp-Grapevine canyons fanhead area, or where topographic obstructions like the Jarilla Mountains create lee side windshadows, like the Jarilla Bolson. Sand does, however, saltate over the northern part of the Jarillas through Sand Gap (see Figure 15).

Primary sand washes into the Jarilla Bolson from extensive Yeso redbeds that outcrop below Otero Escarpment. Most sand, however, is secondary and blows into Jarilla Bolson from the southwest through Jarilla Gap (a wind gap) on the south, around the Moody Lowlands wind gap on the north, and through Sand Gap wind gap in the northern Jarillas. Both the Jarilla Gap and Moody Lowlands have significant SW-NE attenuated lobate and mega-rippled dune piles that, gauging from their thicknesses and polygenetic complexities (e.g., the BLM site), have long been accumulating, probably at least during much of the mid-late Quaternary (see Figures 15-18). The slowly moving dune trains in both areas ultimately merge high on the Grapevine-Culp canyons fanheads. A Venturi effect (a meteorological condition in which wind is funneled with higher than average velocity through a mountain pass or particular wind-channeling area) has apparently channeled winds and sand episodically up into this part of the Sacramento Mountains for a long geologic time, probably well into the Pleistocene (the dune-train process would be interrupted whenever Lake Jarilla formed; see *Paleolakes* section below). Sand blown up onto the Sacramento Mountains Escarpment is invariably washed back down into the basin, a process made evident by abundant reddish fluvial sand exposed in the channel and walls of Sand and Culp canyons. Part of the sand is buried, and part is re-entrained by the wind and recycled up again.

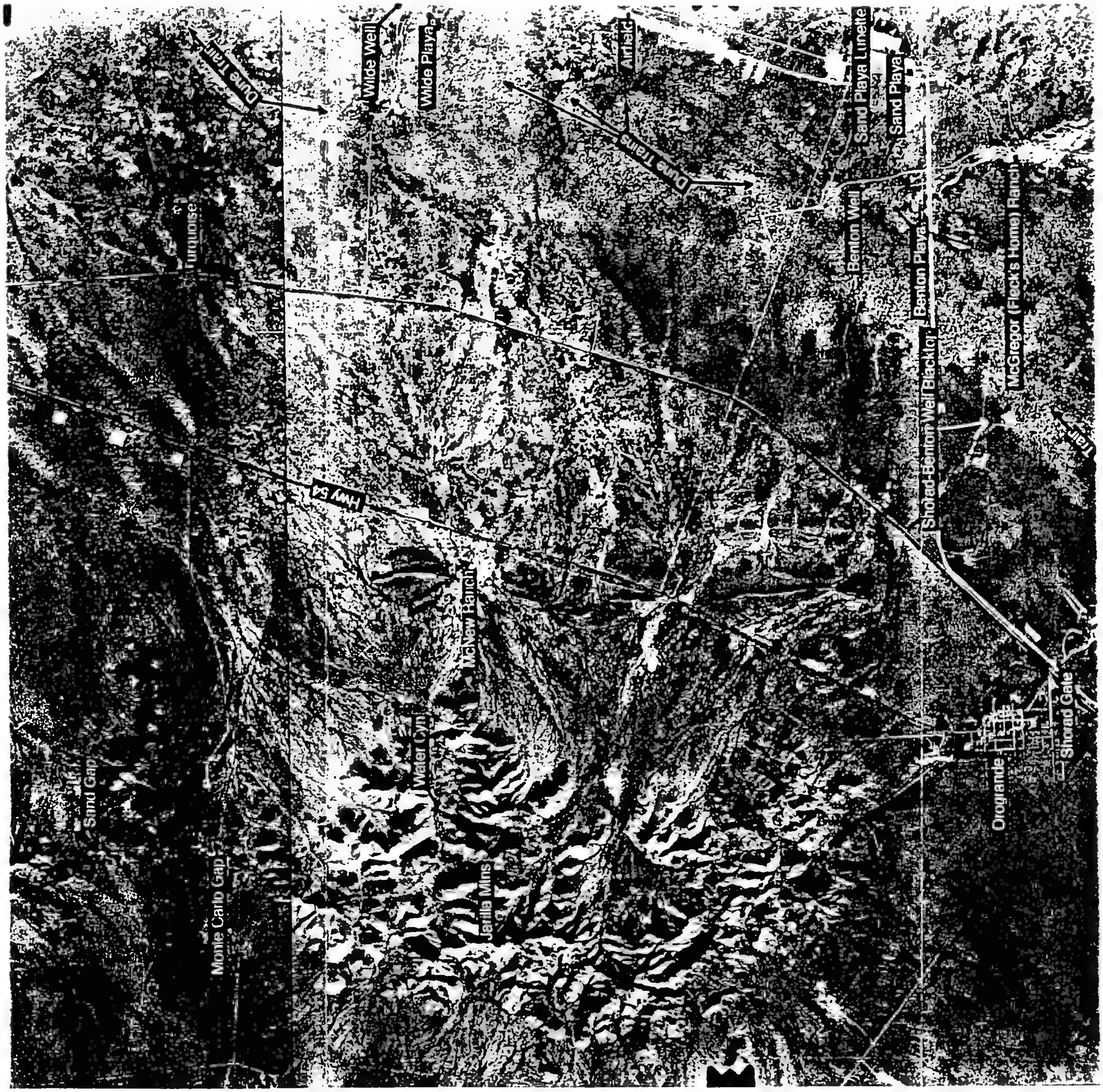
Exposures at the BLM site in the Moody Lowlands reveal the polygenetic and multiple dune sheet character of dune piles in that area (see soil-sediment descriptions, Tres Hermanos quad). Multiple dune sheets that form reddish dune piles also are apparent in borrow pits and road cuts along the Shorad Gate-Benton Well Blacktop, below the Newman (historic) sand.

A local historic source of the reddish sand on McGregor, but which of course also derives ultimately from Paleozoic redbeds, is the extensively eroded A horizon of the La Mesa soil upwind, west and southwest, of the McGregor Range, especially from the Doña Ana Range between Highway 54 and Old Coe Lake. This point was noted earlier, but should be stressed because much eroded La Mesa (Doña Ana) topsoil does indeed contribute to McGregor sand dunes.

The difference between a dune pile and a dune sheet is that dune piles are thick, or consist of multiple dune sheets, or both, whereas a dune sheet is thin. They invariably grade into one another and often occur together, and some dune piles are merely over-thickened dune sheets, and they may or may not be coppiced.


Dune Trail
C.R. 506
Gypsite Flats
Salt Cedar Playa
Turquoise
Paxton Crossing
Hwy 54
Sand Gap
Moody Lowlands
North Tank
Monte Carlo Gap

1



Dune Trail
Wilde Well
Wilde Playa
Airfield
Dune Trails
Sand Playa Lunette
Sand Playa
Turquoise
Benton Well
Benton Playa
McGregor (Fleck's Home) Ranch
Shorad-Benton Well Blacktop
Trail
Hwy 54
McNew Ranch
Water Cyn
Jarilla Mtns
Sand Gap
Monte Carlo Gap
Orogrande
Shorad Gate

②

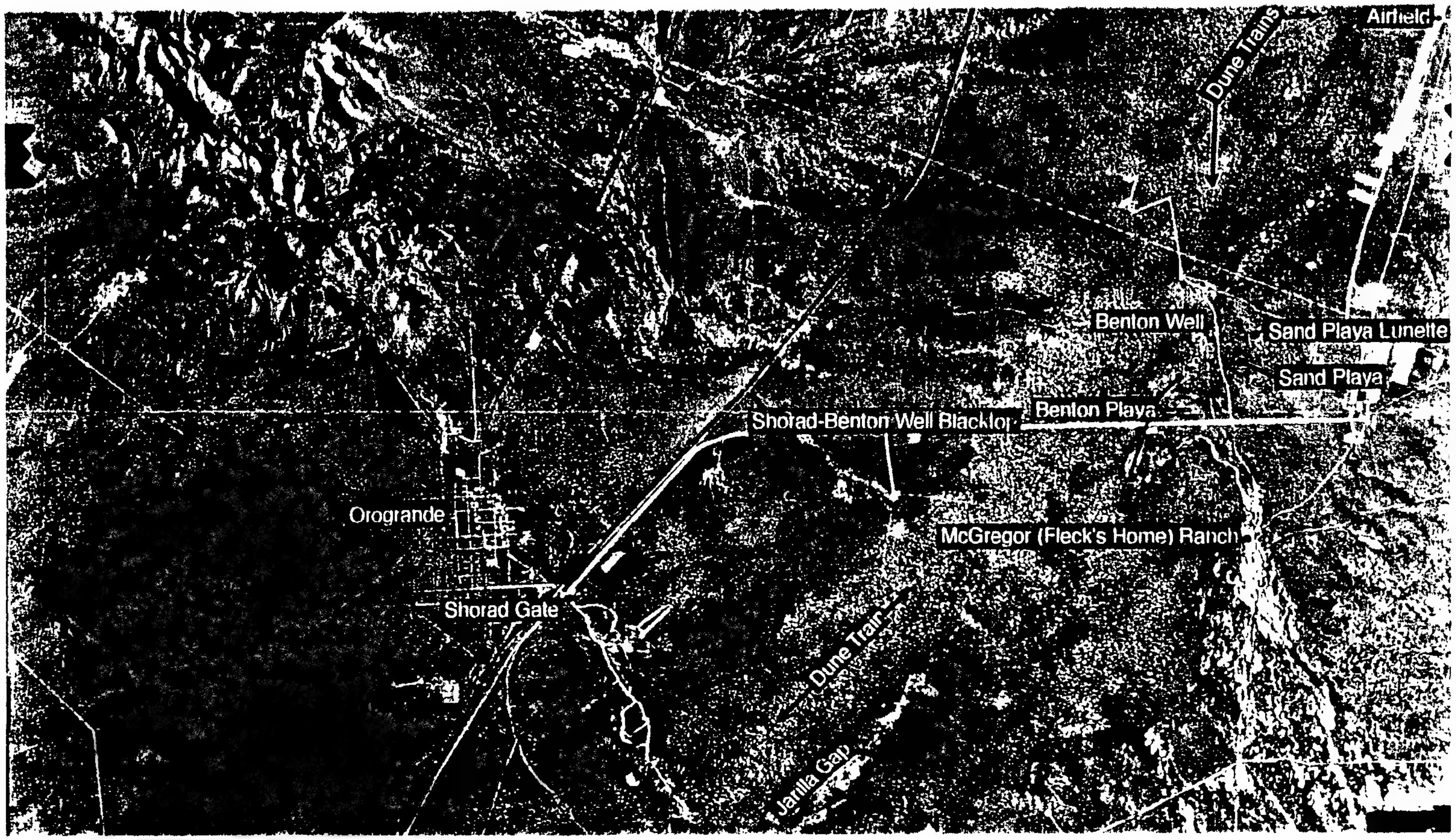
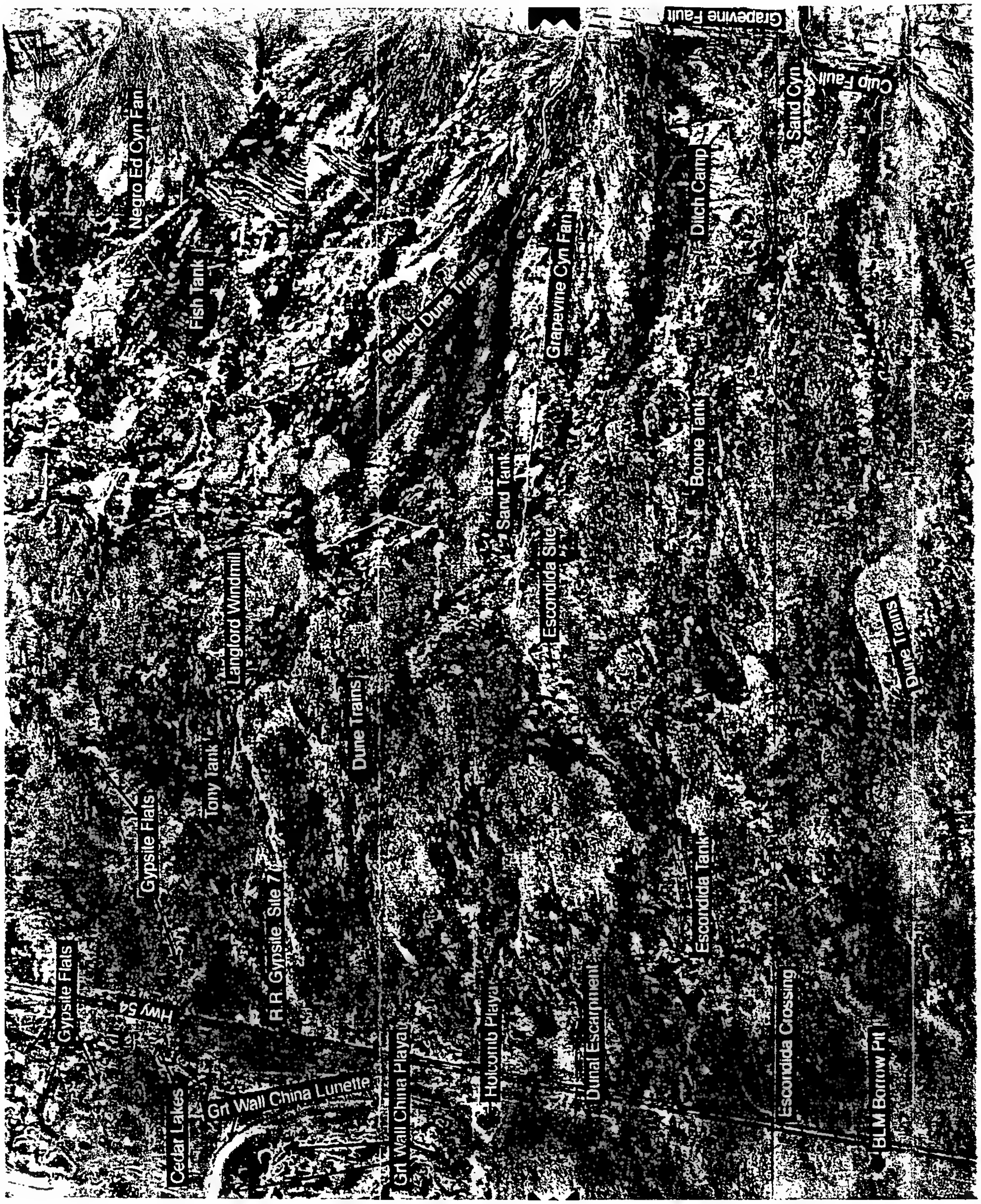


Figure 15. Color infrared (CIR) airphoto (1:40,000) showing lobate dune piles (or dune trains) slowly migrating northward up the Jarilla Bolson in the Benton Wilde Cox wells area of McGregor Range. On the basis of "then and now" land survey records (1880s-1915s, see Kenmotsu 1977) active dune trains are believed to have formed sometime between 1885 and 1901 (cf., Figures 13 and 14). Note temporary playas here and there among lobes of the dune trains. Note also Sand Gap in the Jarilla Mountains through which considerable sand has saltated across the northern Jarillas from the southwest into the Jarilla Bolson.

3



Grapevine Fault
Cuip Fault
Sand Cyn
Ditch Camp
Negro Ed Cyn Fan
Fish Tank
Buried Dune Trains
Grapevine Cyn Fan
Boone Tank
Sand Tank
Escondida Site
Langford Windmill
Dune Trains
Tony Tank
Dune Trains
Gypsite Flats
Gypsite Flats
R.R. Gypsite Site 7
Escondida Tank
Escondida Crossing
Dunal Escarpment
Holcomb Playa
Hwy 54
Grt Wall China Lunette
Grt Wall China Playa
Cedar Lakes
BLM Borrow Pit

1

②

Escondida Site
Grapevine Cyn Fan
Dunal Escarpment
Escondida Tank
Boone Tank
Ditch Camp
Grapevine Fault
Escondida Crossing
Sand Cyn
BLM Borrow Pit
Dune Trains
Culp Fault
Bomb Target
Culp Cyn Fan
N. Culp Paleofan
Pipeline Cyn
Aqueduct
Pipeline Fault #2
S. Culp Paleofan
Culp Fault
Buried Dune Trains
Pipeline Fault #1
W. Grapevine Fault
E. Grapevine Fault
Gypsite Flats
Cox Playa
C.R. 506
Salt Cedar Playa

Figure 16 Lobate dune trains shown migrating north from the Benton/Wilde/Cox wells area across County Road 506, and east northeast out of the Moody Lowlands across the Jarilla Bolson and up onto the Culp Grapevine canyon fans (image taken from the same CIR photo set as Figure 15). Note that north of County Road 506 and across the Culp Grapevine fans, inactive former dune trains are being episodically buried by calcareous alluvium shed from Culp and Grapevine canyons. While the latest, historic episode of land destabilization occurred after 1885, this entire area has been sand-positive during Holocene and probably late Pleistocene times, and has probably experienced prehistoric natural (non overgrazing induced) episodes of land destabilization. The lowest part of the Jarilla Bolson at Salt Cedar Playa is in the lower left of photo.

(3)

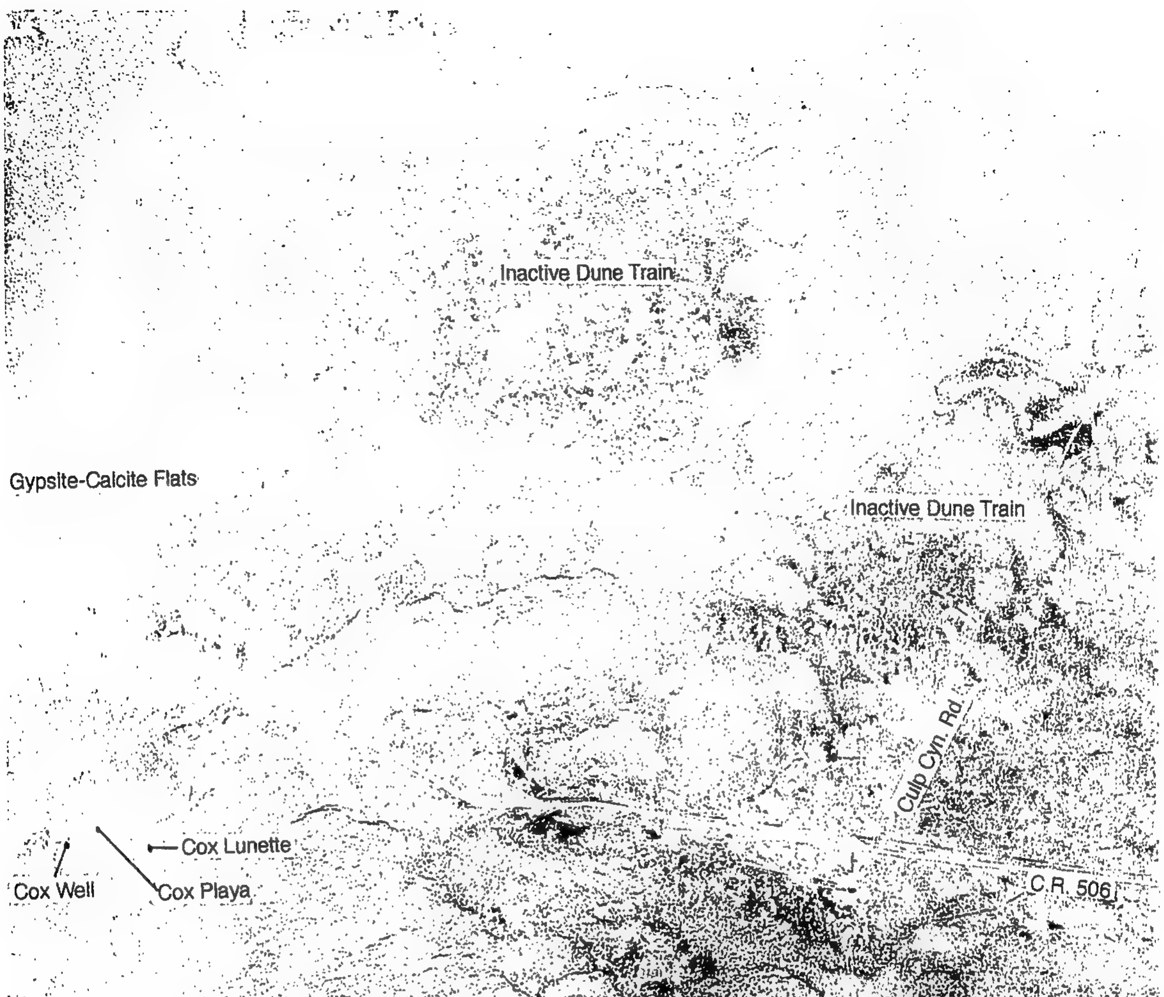


Figure 17. Close-up of a portion of CIR photo showing a northward migrating active dune train south of County Road 506 (see Figures 15 and 16). North of County Road 506 moribund dead dunes—former dune trains—are undergoing active burial by alluvium from Culp Canyon and other watersheds to the east (WSMR 1985, 1:24,000 scale).

Dune Sheets (Uncoppiced and Coppiced)

A dune sheet is a dynamic layer of sand of variable thickness, but generally relatively thin, often less than 2 m (syn., sand sheet). Theoretically sand sheets may be as thin as a few centimeters, or even millimeters at their expanding downwind frontal edge where they are expressed as saltating grains of sand.

Dune sheets may or may not be coppiced. Coppiced dune sheets are more conventionally called coppice dunes (Melton 1940), a practice followed here. A coppice dune is an accumulation of wind-deposited sand or sandy soil about the base of an anchoring shrub (syn., coppice mound). Mesquite is the most common anchoring shrub for coppice dunes in the Tularosa Basin and nearby areas (Gile 1966), and coppices anchored by them may be large. Creosotebush is a less common anchoring species, and coppices anchored by them are smaller. A yucca-grass association, on the other hand, is more typical for uncoppiced dune sheets.

It is important to emphasize that as defined here coppice dunes are a special manifestation of dynamic, on-the-move dune sheets. Inasmuch as the downwind distal front of a dune sheet often attenuates and expands via saltating sand blown from its leading edge, incipient coppicing often begins at extremely small scales, often only a few sand grains thick.

Coppice dunes vary significantly in their character and geometries. In fact, they span a spectrum from subtle sandy or sandy soil accumulations at the bases of creosote shrubs on the one hand, to spectacular, discrete, 3-5- m-high hemispherical mesquite-anchored mounds on the other. The latter may be surrounded by bare and eroded though thick and indurated caliche, and joined to one another only by the sand that saltates between them. Examples on McGregor occur on the Camp Rice (La Mesa) surface along the north-south Water Road between the McGregor Entrance Blacktop and Meyer Range Road. Maximal examples also typify parts of the Doña Ana Range west of McGregor that are underlain by the La Mesa (Doña Ana) soil. Beneath the mounds, intact sandy A horizon of the La Mesa soil is preserved, but stripped down to the petrocalcic horizon elsewhere, showing that much of the coppiced sand came from the nearby eroded intermound La Mesa topsoil itself. But while both minimal and maximal coppice mounds are present on the McGregor Range, intermediate members are the rule.

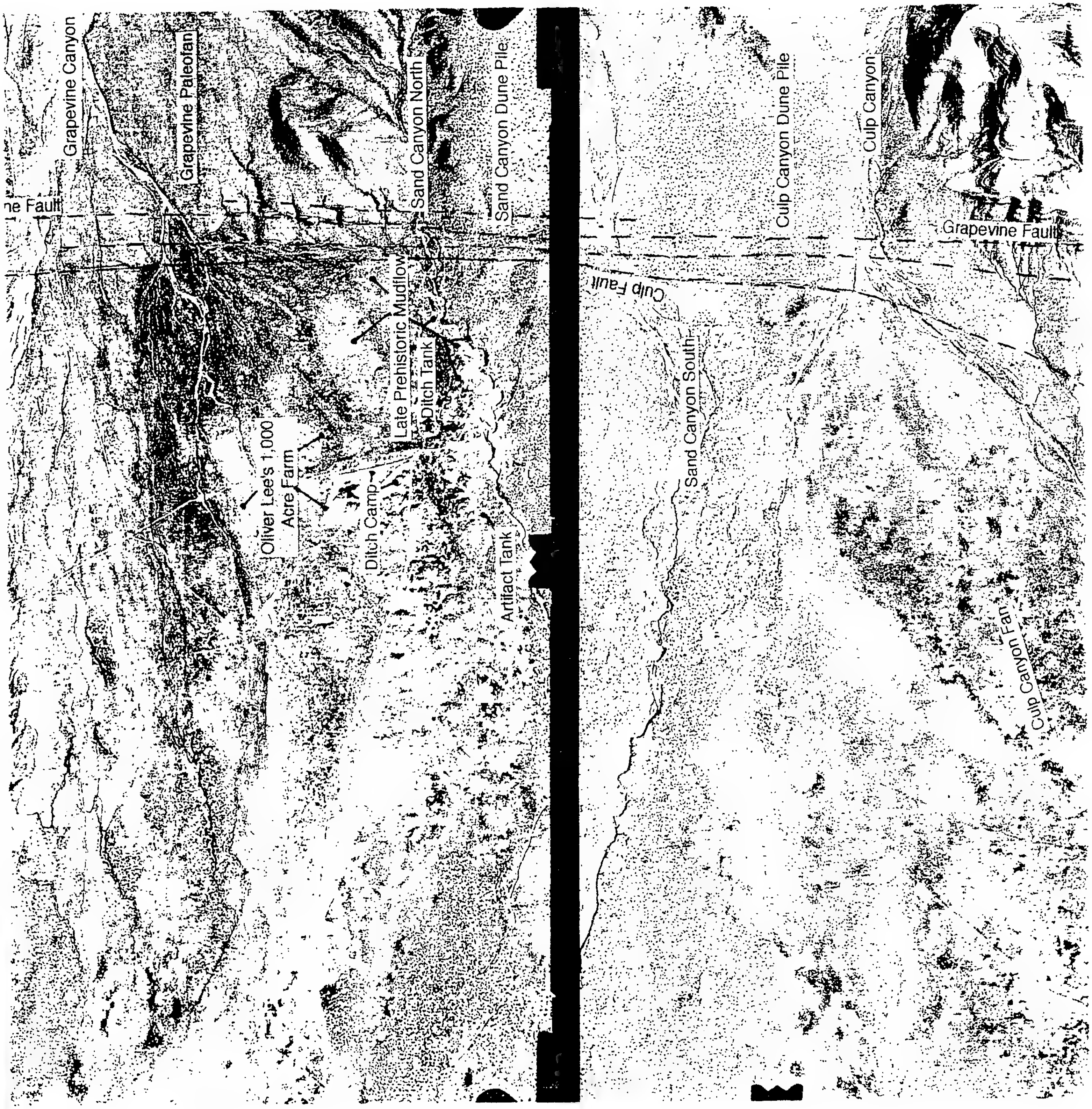
Playa Lunette Dunes

Lunettes in this study range from prominent crescentic sediment plumes deposited by wind downwind of playas (and from which the sediment derived), to low subtle ones that are barely perceptible on the ground. Lunette compositions range from being gypsum-rich (calcium sulphate) to calcite-rich (calcium carbonate) to those composed largely of quartzose sands. Mixtures of the three compositions occur in some lunettes. Gypsum may be massive or crystalline (selenite) in form, the latter typified at White Sands National Monument, the former at the Great Wall of China. Gypsite lunettes form, among other places, on the downwind sides of precipitation-deflation playas (see Playas and Temporary Lakes section below). Examples are in far northwestern McGregor, east of Highway 54 and downwind of the Great Wall of China and Lone Butte playas on the Tres Hermanos quad (mile marker 50, Highway 54). In these playas, shallow and or artesian-fed brackish ground water evaporates at the surface, causing a gypsum-calcite rich effloresced soil to form that is easily deflated by wind, especially if disturbed by ungulates. Over a long period the process removes considerable soil and sediment, causing slow lowering of the playa floor concomitant with the formation of a gypsiferous-calcareous soil dune on the downwind side. Such gypsum- and carbonate-rich soil dunes, doubtless containing a variable quartzose element, are called gypsite lunettes in this report, though they are not differentiated as such on the maps.

Gypsite lunettes also form when playas fill with gypsum-rich runoff waters and when upon evaporation calcite and sulphate are precipitated as an efflorescence at the surface. Wind then piles the playa sediment downwind as a lunette. Gypsum-rich runoff derives from gypsiferous late Paleozoic redbeds and other beds


Bug Scuffle Fault
Bug Scuffle Cyn
Grapevine-Bug Scuffle Paleofan
Grapevine Canyon
Grapevine Paleofan
Grapevine Fault
Culp Fault
Bug Scuffle Fan
Late Prehistoric Mudflow
Oliver Lee's 1,000 Acre Farm
Ditch Camp
Anthropic Tract
Grapevine Canyon Fan
Buried Dune Trains

1


Grapevine Canyon
Grapevine Paleofan
ne Fault
Sand Canyon North
Sand Canyon Dune Pile
Late Prehistoric Mudflow
Ditch Tank
Oliver Lee's 1,000 Acre Farm
Ditch Camp
Artifact Tank
Culp Canyon Dune Pile
Culp Canyon
Grapevine Fault
Culp Fault
Sand Canyon South
Culp Canyon Fan

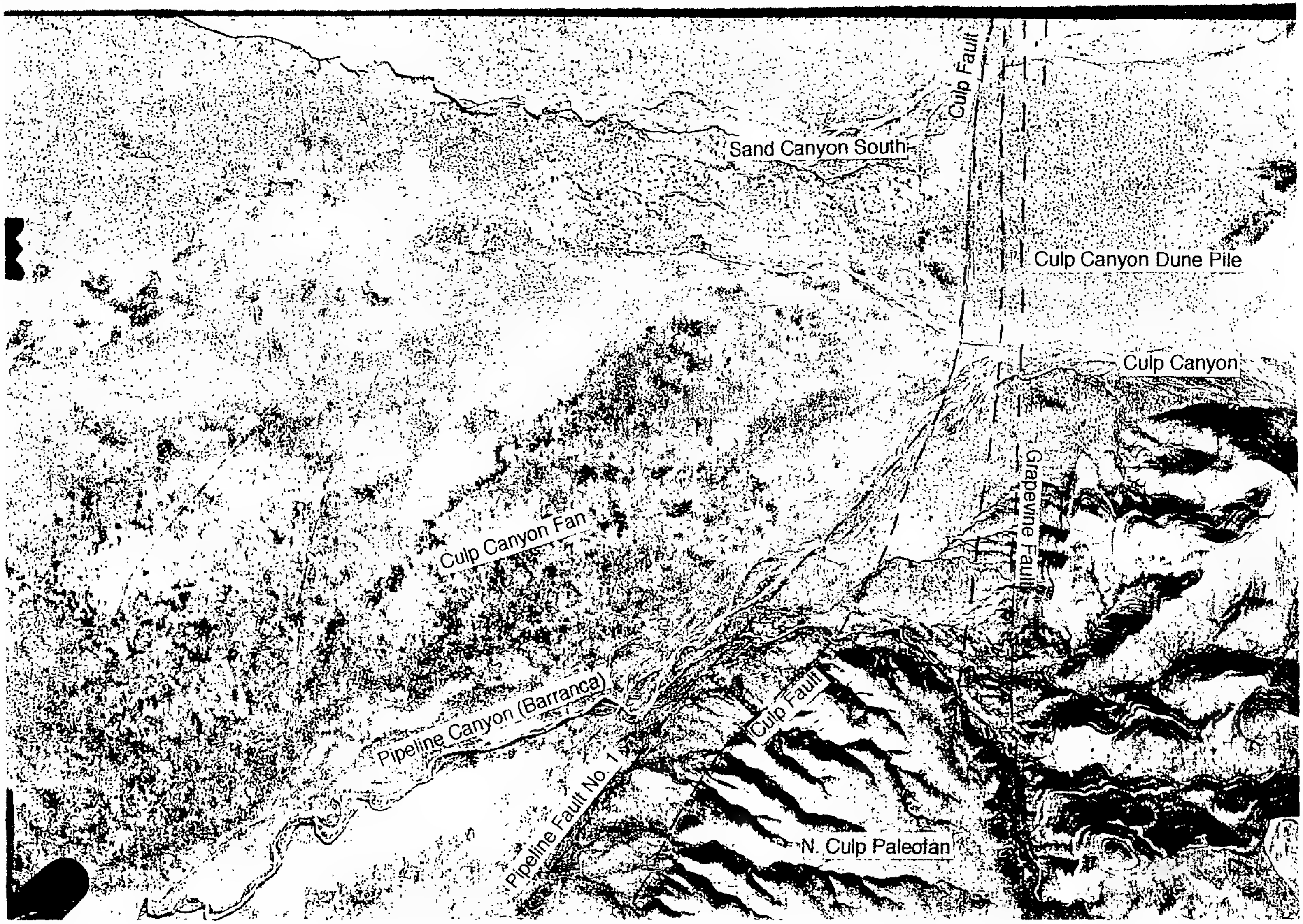


Figure 18. Close-up of a portion of CIR photo showing several active and moribund dead dune trains near the head of Grapevine Canyon fan (see Figure 16). The dead dune trains are undergoing active burial by recent fan alluvium Note faultline scarp expressions of Grapevine, Culp, and Pipeline No. 1 faults, as well as Ditch Camp (Oliver Lee's 1,000-Acre Farm) situated on a late prehistoric mudflow unit vertically exposed in Sand Canyon North (WSMR 1985, 1:24,000 scale, photo taken Dec 11, 1985)

3

in upland rocks, and from gypsum dust deflated from gypsum-rich playas in the western Tularosa Basin (Lake Lucero, White Ranch Lake, Parker Lake, etc.) that periodically blows across McGregor (see Figure 9). Consequently, some of the playas in central and northern McGregor are gypsum-bearing, and all are calcareous. Examples are the lunettes on the northeast of Vertisol and Gypsum playas.

Under the right conditions, a low lobate type of gypsite lunette can form that may attenuate considerable distances downwind of the slowly deepening playa source area. Essentially these are gypsite longitudinal lunettes. Examples are in the north McGregor area, east and northeast of the Great Wall of China gypsite-quartzose lunette and north of the dunal escarpment at mile marker 47 on Highway 54 (Tres Hermanos and Deadman Canyon quads; cf., coppice dune, dune, dune sheet, lunette, alkali lunette, quartzose lunette in Glossary). An example of a quartzose lunette is Benton Well Playa in the Jarilla Bolson (0.5 km north of the Shorad Gate-Benton Well Blacktop and 50 m east of the Benton Well-Sulphur Tank Road; cf., coppice dune, dune, dune sheet, lunette, alkali lunette, gypsite lunette in Glossary).

BEDROCK GEOLOGY

Little has been written on the geology of the McGregor Range per se, though much work has been produced for the Tularosa Basin and surrounding mountains and tablelands. Reynolds and Craddock (1959) did a geological survey of the Jarilla Mountains, and Seager (1961) wrote a Master's thesis on them. Black (1973) executed a thesis on the geology of the Otero Platform. King et al. (1945) studied the geology and structure of the Texas portion of the Hueco Mountains and produced a geologic map at 1:63,360 scale. Hunt (1977, 1978) produced multiple sheets of a geologic map of New Mexico at 1:250,000 scale that emphasizes bedrock and Quaternary geology, which includes the McGregor Range. Barnes and colleagues (1983) produced a geologic map at 1:250,000 scale of the Van Horn-El Paso, Texas, area that includes the El Paso, Hueco Bolson, and Hueco Mountains areas on the southern boundary of McGregor. Seager et al. (1987) produced a geologic map at 1:125,000 scale that covers the western third of McGregor, west of the 106° meridian, which includes most of the southern Tularosa Basin, a map that has proved most useful to this study, though its coverage of McGregor is incomplete (Figures 19 and 20). They also produced a general geologic-tectonic map of the state of New Mexico. Pigott conducted geological and soil reconnaissances and overviews of both the McGregor Guided Missile and Doña Ana ranges (Pigott 1977, 1981) and the Hueco Bolson (Pigott 1978), all in support of archeological work. His McGregor geologic map is included here as Figure 21. Pigott also computed the percent of different rock types on McGregor by surface area, with the following results:

Formation	Percent Total Area
Quaternary Newman Sand	17.91
Quaternary Alluvium	37.06
Tertiary Intrusives	00.28
Permian San Andres Ls.	03.31
Permian Yeso Ls. (San Yesidro Mbr.)	20.62
(Meseta Blanca Mbr.)	01.36
Permian Hueco Ls. Undivided	14.76
(Abo Ss., Upper Mbr.)	00.15
(Pendejo Mbr.)	00.52
(Abo Ss., Lower Mbr.)	00.41
Pennsylvanian Magdalena Gp.	03.41
Mississippian-Devonian Undivided	00.13
Silurian-Ordovician-Cambrian Undivided	00.07
Precambrian Undivided	00.01
	100.00

Limestones

These numbers and studies done to date show that most of the bedrock that immediately underlies the McGregor Range is Paleozoic carbonate rock, mainly Permian limestones with intercalated partly calcareous sandy redbeds (fossil soils). These are Hueco and Yeso formation rocks that variously outcrop on Otero Mesa, along the Broken Escarpment, and in the Hueco and Sacramento mountains. Of these, the Hueco Formation is the dominant bedrock. It outcrops as bedrock outliers that extend northwest from the Hueco Mountains to the Jarilla Bolson (Hueco Bedrock Finger; see Figures 19 and 20). On the eastern side of the Jarilla Mountains the Hueco limestone outcrops as prominent east-northeast dipping cuestas.

Redbeds

Redbeds are a common rock type all around the Tularosa Basin. They have been described by Bachman and Hayes (1958, 1959), Darton (1928), Mack et al. (1991), Pray (1961), and Seager et al. (1987), among others. They consist of the Bliss Sandstone of Cambrian-Ordovician age, and more importantly—in terms of reddish color, quantity, composition and local McGregor impact—the Abo and Yeso formations of lower and upper Permian age. The following descriptions are largely from Seager et al. (1987).

The Cambrian-Ordovician Bliss Sandstone ranges in composition in its lower sections from brown, gray, or black hematitic sandstone, siltstone shale, and quartzite, and grades upward into thin-bedded, siliceous, sandy, orange- to brown-weathering limestone. It outcrops in the Franklin, Organ, and San Andres mountains.

The Lower Permian Abo Formation is a reddish-brown siltstone, fine sandstone, and arkosic sandstone with red, green, and gray shale that in places grades downward into Hueco limestone and upward into, and interfingers with, yellowish, orange and brick red Yeso Formation. The Yeso in many places is gypsiferous, and in places is expressed as a light-brown to light-red to very red sandstone. Both Abo and Yeso have significant outcrops in the McGregor Range in multiple places along the Broken Escarpment, and both contribute significantly to the sand reservoir of the Tularosa Basin.

Plutonic (Igneous) Rocks

Silicic plutonic rocks of Oligocene-Eocene (?) age have regionally intruded Paleozoic carbonates in both the Hueco and Jarilla mountains, in several places north of the Jarillas (Lone Butte and other nearby plutons), in the Organ and Franklin mountains, and in the Cornudas Mountains on southeastern Otero Mesa (King et al. 1945, 1987; Reynolds and Craddock 1959; Seager 1961; see Figures 19 and 20). These igneous intrusive rocks include quartz monzonites, granites, and syenites that were variously intruded as sills, dikes, stocks, bosses, and laccoliths. They form the core of the Hueco Mountains, the most prominent expression of which is Cerro Alto rising to 6,700 ft (2,042 m) elevation. Igneous plutons of the same age also form the rocks on which the University of Texas at El Paso rests (Hoffer 1970). Hueco Tanks and other nearby plutons are quartz syenite expressions of this early Tertiary intrusive episode, as is the small pluton ~2 km SW of Lake Tank near Meyer Small Arms Range (upslope, south of Pluton Pit, site 46, Desert SE quad).

The Jarilla Mountains, which border McGregor Range on its westcentral and northcentral sides, rise about 1,200 ft (366 m) above the Tularosa Basin floor. Pennsylvanian and early Permian limestones and sandy calcarenites make up about half the rock outcrop of the Jarillas, the other half being early Tertiary igneous rocks, mainly granodiorites and monzonite porphyries cut by diabase dikes and sills (Reynolds and Craddock 1959). The igneous intrusions led to contact metamorphism of the limestone rocks, especially in the southern third of the range, and were responsible for significant mineralization in the Jarillas. Turquoise, gold, iron, silver, lead, copper, tungsten, and other ores and minerals were more or less successfully mined before and

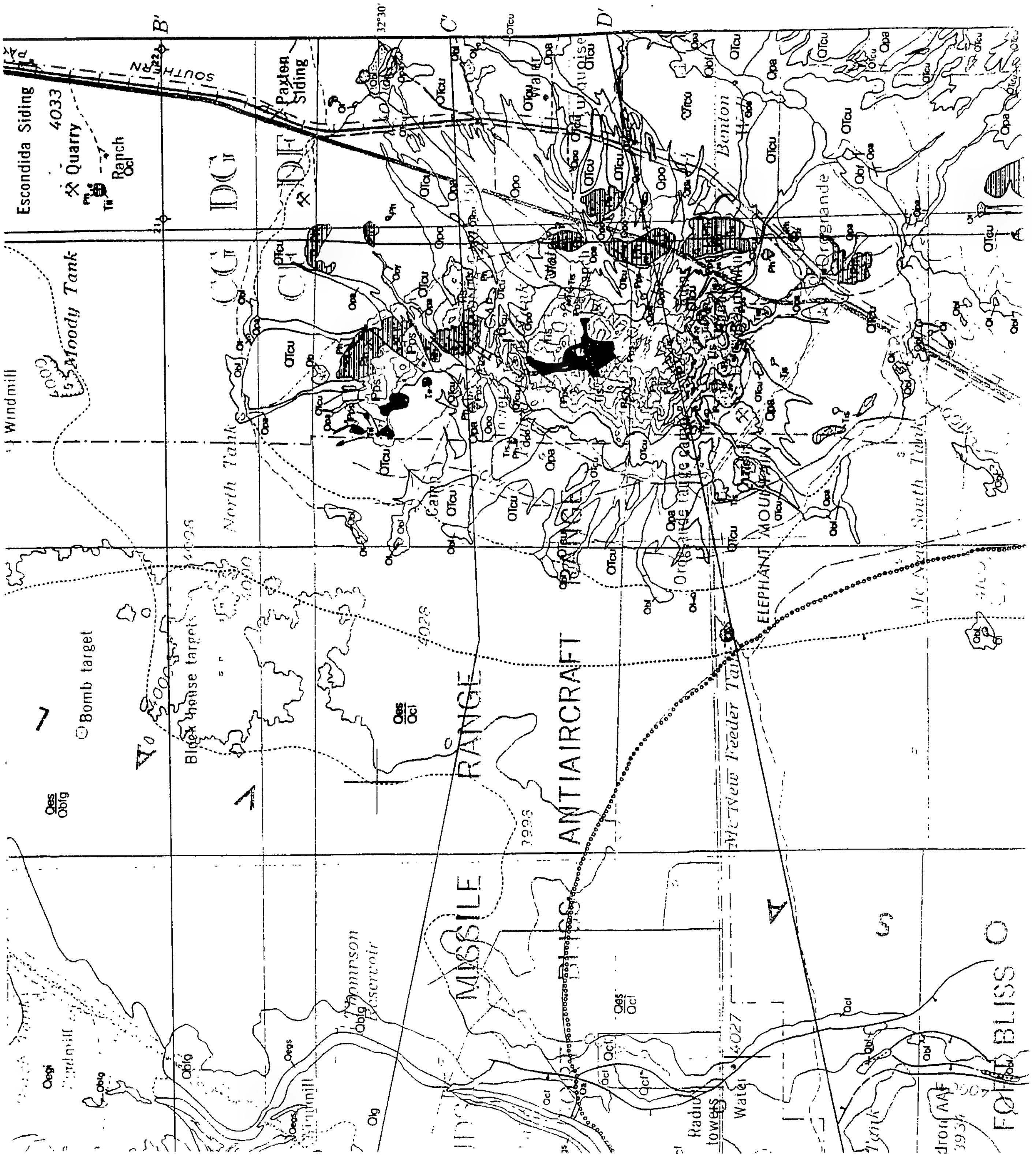
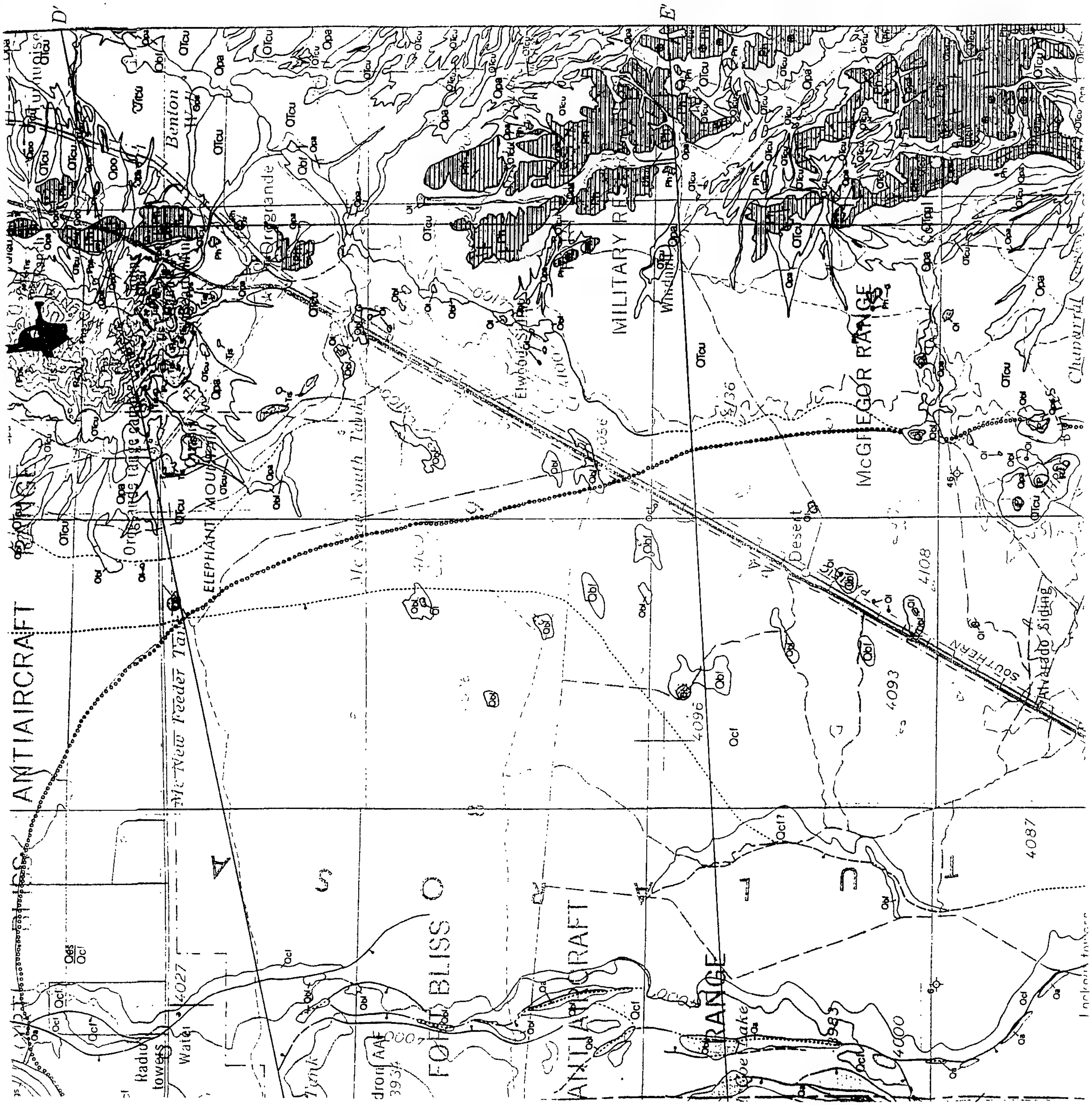
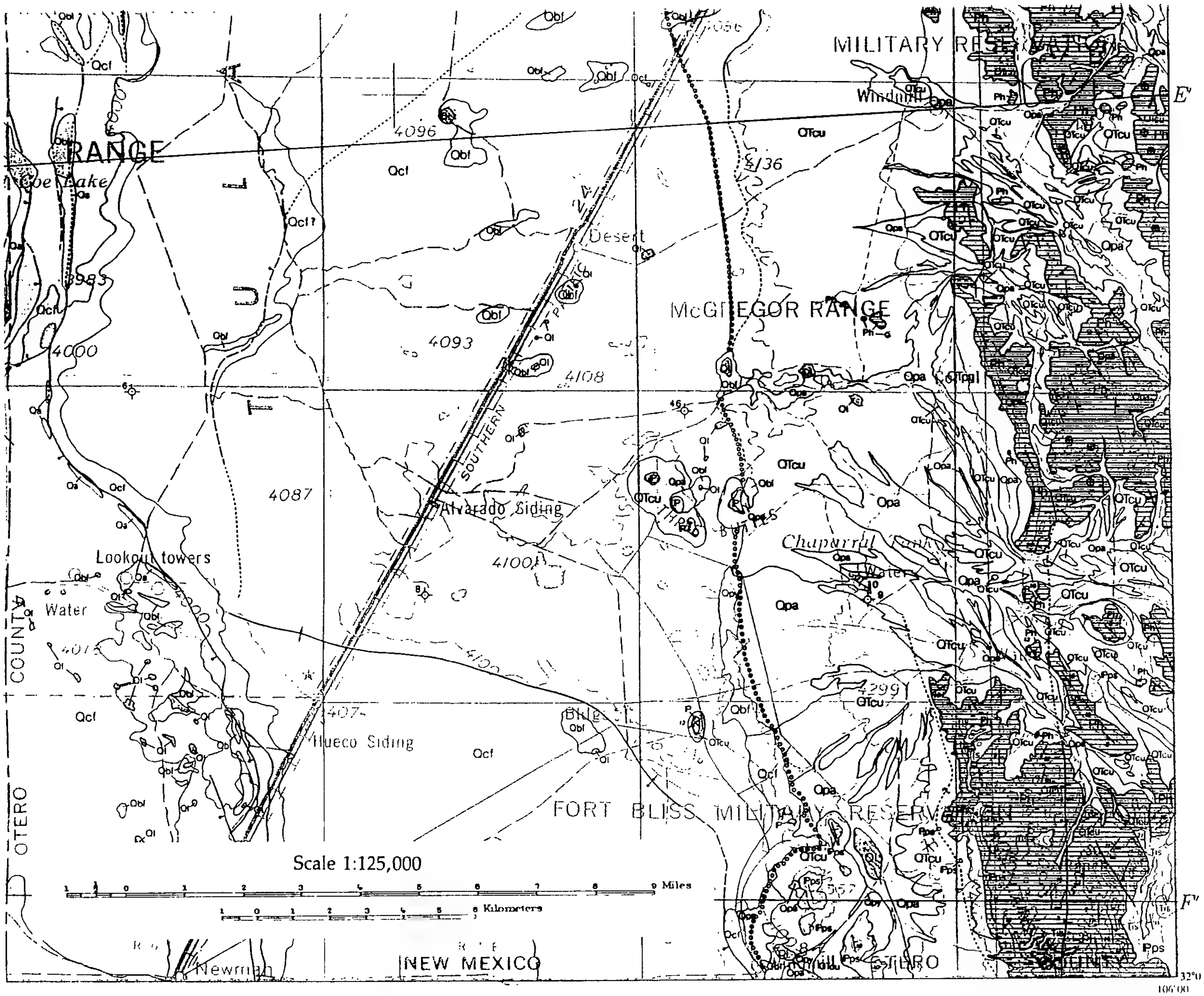


Figure 19. Portion of a geologic map showing part of the southern Tularosa Basin, which includes part of the McGregor Range (Seager et al. 1987; legend follows on

1



h includes part of the McGregor Range (Seager et al. 1987; legend follows on Figure 20).


MILITARY RESERVATION
E'
Windmill
RANGE
McGREGOR RANGE
Desert
SOUTHERN PACIFIC
Alvarado Siding
Lookout towers
Water
Chaparral Tank
Water
Hueco Siding
Bldg
FORT BLISS MILITARY RESERVATION
OTERO COUNTY
Scale 1:125,000
Miles
Kilometers
NEW MEXICO
Newman
OTERO COUNTY
F'
32°0
106°00
4096
4136
4093
4108
4087
4100
4000
4075
4074
4299
Qcf
Qbf
Opa
OTcu
Ph
Pps

DEPOSITS ASSOCIATED WITH YOUNGER BASIN-FLOOR SURFACES AND PIEDMONT SLOPES GRADED TO THOSE SURFACES—Qpy, Qbf, Ql, Qlg, Qes, Qegs, Qega, Qegi *(descriptions of individual units listed below)*

Qpy YOUNGER PIEDMONT-SLOPE DEPOSITS—*Unconsolidated sand, gravel, and loamy sediments of drainageways that cross and are inset below or bury older piedmont slopes, and of fans constructed on distal piedmont slopes at lower end of such drainageways; up to 15 ft thick*

Qbf BASIN-FLOOR SEDIMENTS—*Mostly loam, silt, or clay, locally with thin pebble-gravel zones;* Qbf *deposits in eastern Tularosa Basin are commonly gypsiferous; up to 15 ft thick*

Ql DEPOSITS OF SMALL, NON-ALKALINE PLAYA LAKES AND DEPRESSIONS—*Mostly clay and silt; up to 15 ft thick*

Qlg GYPSIFEROUS LAKE DEPOSITS IN THE TULAROSA BASIN—*Includes large ancestral Lake Otero with highest shoreline near 3,950 ft and several smaller lake beds in the eastern Tularosa Basin; mostly gypsite, gypsiferous red and green clay, and gypsiferous silt, locally covered by thin, loamy to silty, eolian deposits of alluvium; at least 25 ft thick*

Qegs EOLIAN DEPOSITS ASSOCIATED WITH TULAROSA BASIN LAKES—*Mostly inactive, ridge-like dunes of yellowish to tan, gypsiferous quartzose silt and fine quartzose sand with gypsite layers; located on the lee (east) side of lake* (Qlg) *beds; many have 1-2 ft of pedogenic gypsite (gypcrete) capping the deposits; up to 75 ft thick*

Qes EOLIAN QUARTZOSE SAND—*Dunes and irregular hummocks of quartz sand, especially extensive on western piedmont slopes of San Andres Mountains, on the La Mesa surface southwest of Las Cruces, east of San Diego Mountain, and in the southern Tularosa Basin; the sand is derived largely from Camp Rice Formation* (Qcf); *up to 10 ft thick*

Qpo OLDER PIEDMONT-SLOPE DEPOSITS—*Fan and terrace deposits and erosion-surface veneers on piedmont slopes graded to closed-basin floors postdating river-valley incision; mostly weakly consolidated gravel and sandy gravel, grading downslope to gravelly loam, with thin horizons (surficial and buried) of soil-carbonate and clay accumulation; gravelly carbonate horizons are commonly indurated and form thin pedogenic calcretes; at least two generations of fans are present at most places along the San Andres-Organ-Franklin Mountains front; up to 50 ft thick*

Qva UNDIFFERENTIATED Qvy *and* Qvo

Qpa UNDIFFERENTIATED Qpy *and* Qpo

Qbfg OLDER GYPSIFEROUS BASIN-FLOOR DEPOSITS AND LAKE BEDS—*Mostly red and green gypsiferous clay and silt interbedded with gypsite; upper 1-3 ft is gypsite of probable pedogenic origin; unit crops out as high as 3,995 ft and underlies much of the central Tularosa Basin north of the Jarilla Mountains; grades to* Qpg *above 4,000 ft; age of exposed beds is uncertain, probably late Pleistocene, younger than 0.4 m.y.; at least 25 ft thick*

QTcu CAMP RICE FORMATION, Qcp *and* QTcc, UNDIVIDED

Qcl CAMP RICE FORMATION, SEDIMENTS ASSOCIATED WITH LA MESA SURFACE—*Basin-floor sediments, the constructional top of which is the La Mesa geomorphic surface (shown on geologic map with horizontal-line pattern); generally consists of sand, silt, loam, or clay; includes fluvial, playa, and alluvial-flat deposits that are commonly wind reworked; surficial layers, up to 10 ft thick, have prominent horizons of soil-carbonate accumulation and, locally, reddish-brown horizons of clay accumulation; carbonate horizons are commonly indurated, forming pedogenic calcrete zones up to 5 ft thick; unit is overlain by discontinuous veneer of Holocene eolian sand or, locally, by upper Quaternary playa or alluvial-flat deposits; up to 60 ft exposed; may be locally thicker in subsurface*

Qcp CAMP RICE FORMATION, PIEDMONT-SLOPE FACIES—*Deposits associated with piedmont slopes graded to basin floors predating river-valley incision; weakly to moderately cemented, boulder to cobble fan deposits and erosion-surface veneers near mountain fronts grading to gravelly silt, loam, or clay on distal piedmont slopes; discontinuous lenses of volcanic ash (0.6-0.7 m.y.; Gile and others, 1981) are locally present; surficial layers, up to 10 ft thick, usually with prominent horizons of soil-carbonate accumulation and, locally, reddish-brown horizons of clay accumulation; gravelly carbonate horizons are commonly indurated, forming pedogenic calcrete zones up to 5 ft thick; multiple buried soils are present in thicker deposits; generally less than 80 ft thick*

Qcf CAMP RICE FORMATION, FLUVIAL FACIES—*Tongues of ancestral Rio Grande deposits comprising gray to yellow sand, pebble to cobble gravel, calcite-cemented sandstone and conglomerate, and gray, green, or red loam to clay with minor volcanic-ash lenses; subrounded to subangular siliceous pebbles derived from upstream sources are common; locally intertongues downward with* QTcc *and upward with* Qcp; *over much of the Mesilla Basin, Jornada Basin, and southern Tularosa Basin, the constructional top of* Qcf *is the La Mesa surface (shown on geologic map with horizontal lines); sand dunes* (Qes) *covering* Qcf *were mapped locally; ash lenses near the base of the unit are approximately 2.0 m.y. old (Strain, 1980); near the top, approximately 0.6-0.7 m.y. old (Gile and others, 1981); interbedded basalts are as old as 2.9 m.y. in south-central New Mexico (Bachman and Mehnert, 1978); interpreted to be 700 ft thick in subsurface of east-central Mesilla Basin (Wilson and others, 1981)*

Tis SILICIC PLUTONIC ROCKS (OLIGOCENE AND EOCENE?)—*Quartz-monzonite porphyry, granite, quartz syenite, and syenite of the Organ batholith; monzonite-porphyry dikes, small stocks, and a laccolith of the Doña Ana Mountains; monzonite-porphyry dikes, sills, and stocks of the Jarilla Mountains; and syenitic sills and associated stocks (?) or laccoliths (?) in the Hueco Mountains; the Organ and Doña Ana intrusives (32.8 m.y. and 33.7 m.y., respectively; Seager, 1981; Loring and Loring, 1980; Seager and others, 1976) are associated with thick cauldron-fill, ash-flow tuffs; the Organ intrusives also are related to mineralization in the Organ mining district; the Jarilla intrusives (late Eocene? or Oligocene?) are related to mineralization in the Orogrande district*

INTERMEDIATE-COMPOSITION PLUTONIC ROCKS (OLIGOCENE AND EOCENE)—*Medium- to dark-gray, equigranular monzodiorite stock in the Organ Mountains (~33 m.y.; Seager, 1981) largely obliterated by younger phases of the Organ batholith; grandiorite stock of the central Jarilla Mountains (47.1±1.8 m.y.; Beane and others, 1975) and andesite porphyry to diorite of Cristo Rey pluton and Vado Hills (47.1±2.3 m.y. by analogy with Campus Andesite; Hoffer, 1970)*

Ph HUECO FORMATION—*Algal limestone, gastropod-echinoid-brachiopod limestone, fusulinid limestone, chert-pebble conglomerate, sandy limestone, gray shale, shaly limestone, siltstone, massive cherty limestone; in the Doña Ana Mountains, sandstone, porcellanite, black shale, and stromatolitic limestone; light to dark gray, cream, yellow, orange; Wolfcampian (Early Permian) age; 1,900 ft thick in the Robledo Mountains (including both a tongue of Abo Formation 320 ft thick in the upper part and, at the base, approximately 200 ft of limestone correlative with Bursum Formation; Seager and others, in preparation); as much as 2,250 ft thick in the Doña Ana Mountains (Seager and others, 1976); 1,450 ft thick in the southern San Andres Mountains, thinning northward to 325 ft thick at Hembrillo Canyon (Kottlowski and others, 1956; Bachman and Myers, 1969; Seager, 1981); 1,900 ft thick in the central Organ Mountains (Seager, 1981); 3,620 ft thick in the Grimm and others deep oil test (Thompson and Bieberman, 1975); at least 2,300 ft thick in the Franklin Mountains (Harbour, 1972); and 1,600 ft thick in the Hueco Mountains, including approximately 100 ft of basal Powwow Conglomerate Member (Hardie, 1958)*

IPps PANTHER SEEP FORMATION—*Brown to gray shale, sandstone, siltstone, gypsum, and fine-grained, laminated limestone, mostly of Late Pennsylvanian age, deposited in the Orogrande Basin; grades downward into Middle Pennsylvanian beds and upward into Hueco Formation; approximately 1,800 ft thick near Hembrillo Canyon; 2,500 ft thick in the Ash Canyon-San Andres Canyon area (Kottlowski and others, 1956); approximately 2,000 ft thick in the southern San Andres and Organ Mountains (Bachman and Myers, 1969; Seager, 1981); approximately 2,400 ft thick in the vicinity of the Jarilla Mountains (Kottlowski, 1960c; this study); approximately 1,200 ft thick in the Franklin Mountains (Harbour, 1972); and at least 1,200 ft thick in the northern Hueco Mountains (Hardie, 1958)*

IP PENNSYLVANIAN ROCKS, UNDIFFERENTIATED—*Includes massive- to medium-bedded, cherty, fossiliferous limestone, interbedded shale, shaly limestone, and minor sandstone; as much as 1,500 ft thick (Harbour, 1972); correlative with Lead Camp Limestone; also correlative with La Tuna, Berino, and Bishop Cap Formations of the Bishop Cap-northern Franklin Mountains and with the Gobbler Formation of the Jarilla-Hueco Mountains area; in the Robledo Mountains, the unit includes shelf limestones and shale, approximately 640 ft thick, correlative with both Lead Camp Limestone and Panther Seep Formation and representing rocks ranging from Derryan to Virgilian (Early to Late Pennsylvanian) in age (Seager and others, in preparation)*

IPM PENNSYLVANIAN AND MISSISSIPPIAN ROCKS, UNDIFFERENTIATED

SYMBOLS

- Contact, dashed where inferred
- Normal fault, ball on downthrown side, dashed where inferred at the surface, dotted where buried and/or inferred in the subsurface
- Thrust or reverse fault, barbs on upthrown side
- Limits of landslide blocks
- Monoclinal axis, dashed where inferred
- Anticlinal axis
- Synclinal axis
- Axis of overturned syncline
- 66 Strike and dip of foliation in Precambrian metamorphic rocks
- 17 Strike and dip of bedding, or of foliation in ash-flow tuffs
- Horizontal beds
- Strike of vertical bedding, or of foliation in ash-flow tuffs
- 70 Strike and dip of overturned beds
- Approximate known limits of fluvial deposits of Camp Rice Formation (ancestral Rio Grande deposits)
- Selected oil or water test holes; number adjacent to symbol corresponds to well listed in Table 1. Data from Knowles and Kennedy, 1958; Kottlowski and others, 1956; Thompson and Bieberman, 1975; King and others, 1971; Doty and Cooper, 1970; Wilson and others, 1981; Wilson and Myers, 1981; King and Harder, 1982; Texaco, Inc.; Exxon, Inc.; Permian Basin Sample Laboratory; Foster, 1978; and Kelly, 1973.

Figure 20. Legend for the Seager et al. (1987) geologic map (see Figure 19).

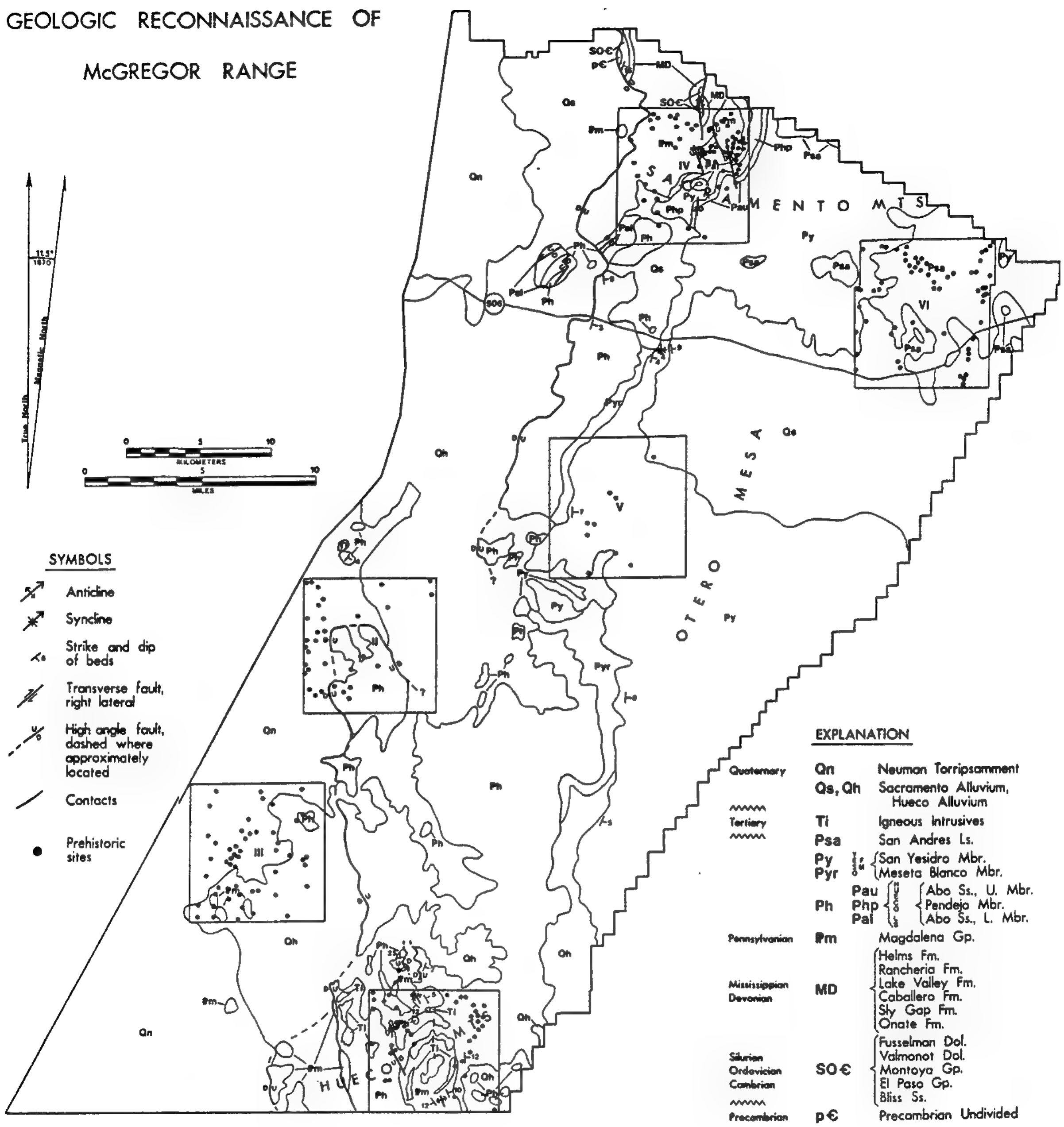


Figure 21. Reconnaissance geologic map (Pigott 1977:Figure III-10).

after the turn of the century. A small area of vesicular basalt (pahoehoe) possibly associated with a volcanic pipe, occurs north of the main part of the Jarillas that Reynolds and Craddock (1959) suggest is late Tertiary in age.

According to Reynolds and Craddock (1959) the Jarillas appear to be a much intruded north-northwest trending anticlinal structure, whereas Herrick and Davis (1965) suggest they are a partly buried fault-block

ridge, possibly the result of step faulting along the east side of the basin. The presence of many minor and several large faults in the Jarillas, most of which strike northeast, the presence of a north-south trending mini-graben (Jarilla Bolson) on their east border, and the confirmed (this study) presence of normal step faulting along the Otero-Sacramento escarpment collectively suggest an intruded, partly buried fault-block ridge. The Jarillas formed in early-mid Tertiary time as a mineralized pluton that intruded upward into overlying late Paleozoic carbonate rocks. Remnant carbonates flank the east and north sides of the Jarillas as outward dipping limestone cuestas. Late Paleozoic carbonates are also exposed in several low hills and bedrock highs that extend north from the Jarilla Mountains to and beyond Highway 70 and beneath the White Sands gypsum dunefield. The bedrock high is part of the Jarilla Mountains mini-horst situated within the much larger Tularosa Basin graben. Normal step faulting between the Jarillas and the Otero Platform probably formed the mini-horst, and the Jarilla Bolson mini-graben that lies between.

STRUCTURE AND FAULTS

Rio Grande Rift

No assessment of the geomorphology and landscape evolution of the McGregor Range or the southcentral New Mexico area would be complete or even valid without acknowledging the overwhelming and dominant role of geologic structure and faulting. Fitzsimmons (1955) had this to say about geomorphology and structure of the region:

> The gross physiographic features of south-central New Mexico are fundamentally primary structural features, and, consequently, any study of the geomorphology of this area must be but an appendix to the discussion on structure. Of course, land forms everywhere reflect structure, but here the modifying effects of erosion have done less to obscure the major structural dislocations than in many other parts of the country.

Pigott (1977:130) stated that "[t]he hydrology of McGregor Range is both structurally and lithologically controlled." Fitzsimmons' and Pigott's statements are more than confirmed by this study. Structural processes, especially faulting, and probably jointing patterns, are not only responsible for almost all gross physiographic features of McGregor, they are also responsible for many of the individual landforms and for the entire geomorphic grain of the dissected bedrock and pediment terrain between Otero Mesa and the Tularosa Basin. They are in fact responsible for origin of the Tularosa Basin and all the mountains surrounding it.

A general structural-tectonic map of southcentral New Mexico includes the western third of the McGregor Range (Figure 22). The area is part of the much larger Rio Grande rift zone, which itself is part of the larger Western Cordilleran zone of continental extension (Chapin 1971). The Rio Grande rift is a series of late Cenozoic sedimentary basins and volcanic fields which range from central Colorado south into Mexico. The Tularosa Basin and surrounding mountains are a manifestation of this structural context. Keller and Cather (1994) have recently assembled an array of information on the Rio Grande rift.

Grabens (Basins, Bolsons) and Horsts (Mountains)

The southern part of the Tularosa graben is fronted on the east by the stratified Sacramento Mountains (north) and Otero Mesa (south) whose strata dip east, and fronted on the west by the largely stratified San Andres-Organ mountains whose strata dip west. The whole was a regional anticline whose central part downdropped to form a basin with bounding escarpments, and whose flanks now form outward dipping strata eroded into mountains. The Jarilla Mountains are thought to be an intruded, small block mini-horst ridge in the eastern

TECTONIC MAP

Figure 22. Tectonic map of New Mexico (modified from New Mexico Highway Geologic Map, NMGS 1982).

center of the large graben which formed the Tularosa Basin. Faults are common on either side of the basin, in the Jarillas, the Sacramentos, and on Otero Mesa.

Faults

Several obvious faults were mapped in this study, several were mapped that are less obvious, some were taken from published work, and all were named to facilitate communication. All faults that first appear in this study were identified on air photos usually using more than one of the following criteria: offsets (bedrock or alluvium), lineations (colors, vegetation), topography (depressions), oriented streams, and oriented playas. Several faults were verified in the field, but others were not and were provisionally inferred from air photos. Most faults are assumed to be recent or late Quaternary in age. The compilation below names the faults, identifies the quad maps on which they occur, and ranks them as V= verified, UVc=unverified but reasonably certain, UVu=unverified and uncertain, and PM=previously mapped by others:

Fault Name	Quad Maps	Rank
Borrego Ridge Fault	Desert SE	UVu
Bug Scuffle Fault	Bug Scuffle Canyon	V
Charley Tank Fault	Desert SE	UVu
Coyote Fan Fault	Desert SE	VPM
Coyote Ridge Fault	Desert SE	UVu
Culp Fault	Pipeline, Culp, Bug Scuffle canyons	V
Escondido Fault	Deadman Canyon	V
Grapevine Fault		V
E. & W. Grapevine Faults	Pipeline, Culp, Bug Scuffle canyons	V
Grey Tank Fault	Owl Tank Canyon W	UVu
Hackberry Tank Fault	Owl Tank Canyon W	UVu
Hueco Fault No. 1	Desert SE	PM
Hueco Fault No. 2	Desert SE	PM
Hot Well Fault	Newman, Desert SW	VPM
Jarilla Bolson Fault	Orogrande S	UVc
Lake Tank Fault	Desert, Desert SW & SE	V
Lee Fault	Wilde Tank	V
Newman Fault	Newman	V
Pipeline Fault No. 1	Pipeline Canyon	V
Pipeline Fault No. 2	Pipeline Canyon	UV
Red Horse Tanks Fault	Owl Tank Canyon W	UVu
Sacramento Escarpment Fault	Deadman Canyon	V
Snail Playa Fault	Desert SW	UVu
Three Buttes Fault	Desert, Desert SW	V
Wilde Fault	Wilde Tank	V
Wright Fault	Wilde Tank	V

Most of these faults are discussed in the Geomorphology and Soils section in more detail.

HYDROLOGY AND WATER RESOURCES

In a desert area like the Tularosa Basin, water availability ultimately determines whether people, animals, and plants can live in the area permanently or temporarily, and in fact controls their numbers. Water in the form of storm runoff is a major force of geomorphic work on alluvial fans. Water infiltrates downward and recharges water tables, which controls spring discharge and rates thereof. And, of course, water episodically fills playas, an important resource for humans and other biota.

Rain and melting snow infiltrate soils and sediments via wetting fronts and free water recharge that translocate materials (calcium carbonate, clay) from the surface to the subsurface. Hence, an understanding of water resources on the McGregor Range is a key aspect of a study such as this. Water resources include

the amount and kind of precipitation (rainfall, snow), streams, springs, the nature of the water table and its quality (deep, shallow, artesian, saline, alkaline, fresh, etc.), playas, and the existence or former existence of lakes and paleolakes.

Rainfall and Snow

Rainfall records in southcentral New Mexico began in El Paso in 1850 at old Fort Bliss on the Rio Grande and were continued, with interruptions, until 1861 (Meinzer and Hare 1915). After the Civil War observations were continued with interruptions until the end of 1876. An official weather station was established in El Paso in July 1878, and observations since then have been fairly complete. El Paso, then, has an interrupted record of 145 years, 1850-1995, and a complete record of 119 years, 1878-1995. After the turn of the century, 12 other stations started up at different times and places, and all experienced interruptions except one, White Sands National Monument, which began in 1938. The 13 weather stations in the McGregor Range area of New Mexico and Texas are listed below (Figure 23):

Station	Years of Record	Total Years	Average Annual Precipitation (in)	Complete Records
Alamogordo	1914-1995	82	11.56	no
Alamogordo 1	1901-1943	42	12.43	no
Cloudcroft	1902-1987	86	26.60	no
Cloudcroft 2	1901-1949	49	31.65	no
El Paso	1850-1995	145	8.65	no
Escondida Siding	1914-1914	<1	—	no
Las Cruces	1901-1995	95	8.30	almost
Lulu	1948-1961	14	10.48	no
Mayhill Ranger Station	1917-1976	60	19.16	no
Mountain Park	1912-1995	84	19.96	no
Newman	1909-1933	25	8.51	no
Orogrande	1904-1995	92	10.11	no
White Sands Missile Range	?	?	?	?
White Sands National Monument	1939-1995	57	8.95	almost

The stations cover a combined precipitation record from 1850 to 1995, a period of 145 years. Precipitation for White Sands Missile Range exists but is not available (K. Kunkle, personal communication 1996). Although no record is complete, some are nearly so, and collectively they provide a useful overview of the daily, monthly and annual precipitation pattern of the southern Tularosa Basin and adjacent uplands.

Appendix B summarizes these records. The data were compiled largely from the monthly Climatological Data sheets published by the National Oceanographic and Atmospheric Administration (NOAA) and its predecessor, the USDA Weather Bureau (greatly aided by Dr. Ken Kunkle, Illinois State Water Survey). The early El Paso record is from Meinzer and Hare (1915), and part of its later record from Knowles and Kennedy (1958). Since daily precipitation records would have greatly expanded Appendix B beyond practical limits, they were omitted. However, daily records were examined for each station, and major storm events duly noted, as were exceptionally wet days and sets of days, wet months, and wet and dry years.

To provide a regional measure of major storm events, storms that produced two or more inches (5 cm) of rain in one day were identified (see Appendix B). Two or more inches per day was arbitrarily assumed to indicate major storms that would likely cause erosion and contribute to playa filling. Obviously a two-inch rainstorm in one hour would have far more impact than two inches spread over 24 hours.

The collective records of all stations show a general consistency of monthly and annual precipitation across the region. That is, most storms are not isolated single storms that affect only one small area, then dissipate, though cases of the latter are not uncommon. Most storms are usually part of a larger more sustained weather pattern involving multiple thundercells that contribute precipitation regionally, though individual centers may drop more rain here than there.

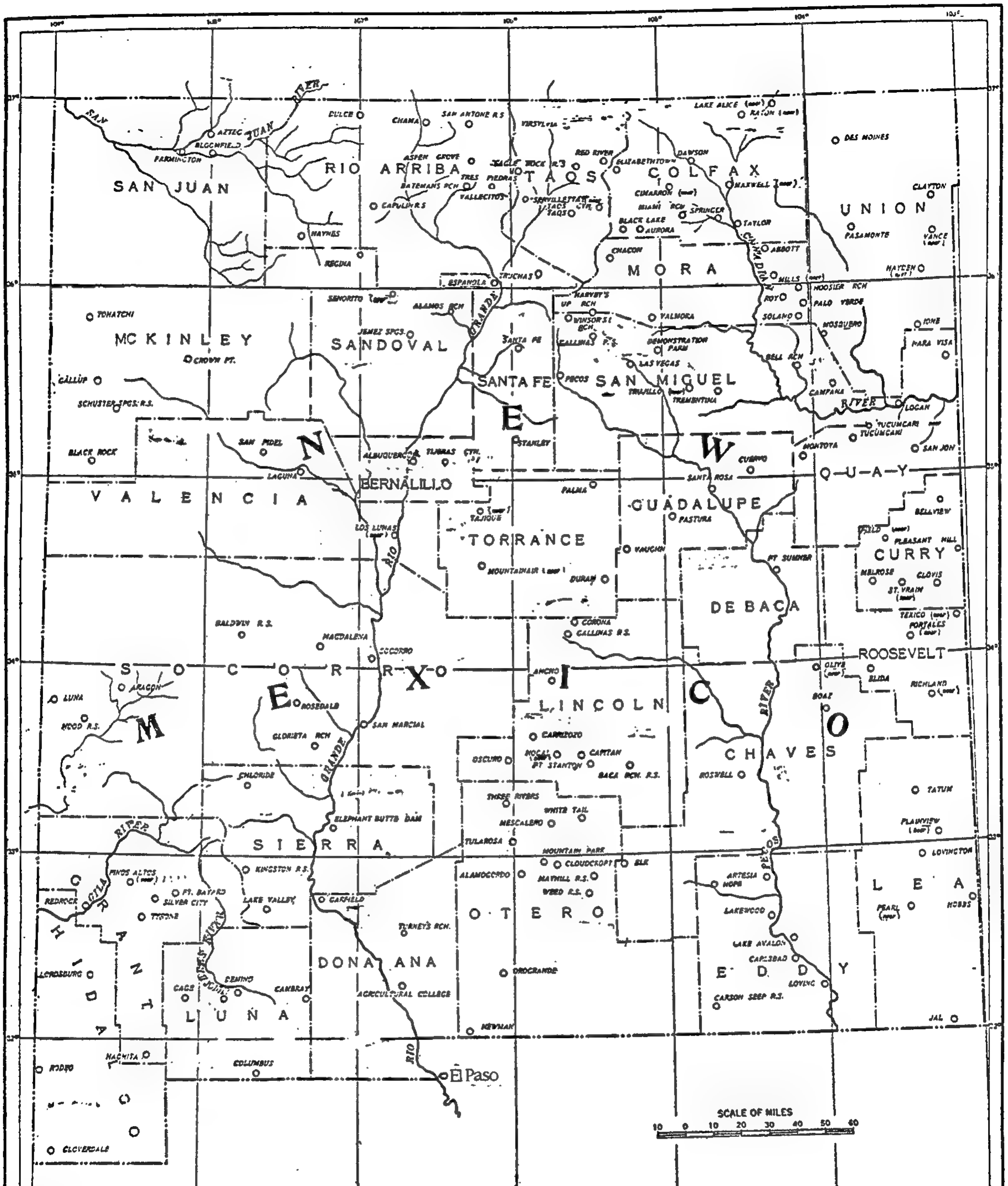


Figure 23. Locations of weather stations in southcentral New Mexico whose data were used for inferring McGregor Range weather and climate (modified from map in Climatological Data:New Mexico section, for year 1928, WBO, Denver, Feb. 27, 1929).

At all stations precipitation is mainly as rain, though in winter snow in modest to significant amounts may fall at Cloudcroft, Mayhill, and Mountain Park (on March 6, 1958, two feet of snow fell on Cloudcroft). Periodic winter snows and snow dustings in the Tularosa Basin are important ecologically, but in terms of total precipitation amounts they are much less important than rain. Snow is usually modest in amount on Otero Mesa and the Hueco Mountains, though occasional drifts of six to seven feet have been recorded (Charlie Lee and Pete Atkins, personal communication 1996).

Most precipitation occurs during the six months of May-October, reflecting the summer monsoonal air flow from the Gulf of Mexico to the southwestern USA and northern Mexico. The data clearly indicate a strong summer rainfall peak. For example, during the regionally wet years of 1914 and 1941 at Alamogordo, Cloudcroft, Las Cruces and Orogrande, the percent of precipitation contributed by the summer monsoonal months of May-October was 73 and 74, 70 and 75, 61 and 75, and 66 and 81, respectively. Likewise, during the regionally dry year of 1945 and the regionally quasi-normal precipitation year of 1980, the percentages were 86 and 80, 76 and 73, 90 and 63, and 85 and 81, respectively.

These examples reflect the general pattern of all stations in Appendix B, which is that most precipitation is associated with monsoonal flow during May through October, and which falls as rain. Consequently, it is summertime monsoonal rains that do most of the geomorphic work on the McGregor Range and that produce temporary lakes in its playas.

However, some of this precipitation is not always due to regional weather systems that affect all stations. Individual storms may be superimposed upon regional patterns and produce prodigious rain at one site, but little at another, indicating that a single storm can form, rain heavily, then dissipate before its effects can be significantly felt at another site. The storm of August 19, 1978, in the western Tularosa Basin proves this point. On that day it rained 10 inches at San Augustine Ranch near White Sands Missile Range Headquarters, five inches of which fell during the first hour (Mr. Rob Cox, personal communication 1997; the Cox family has recorded precipitation for over 40 years at San Augustine Ranch, since the 1920s). Ken Kunkle (personal communication 1997), former State Climatologist for New Mexico, was at White Sands that day and recalls the storm as being exceptionally intense, with Headquarters property inundated by floodwaters. The debris and mudflows shed off the Organ Mountain slopes buried fences and caused great havoc. The hail that accompanied this storm, according to Cox, was intense and killed many jackrabbits and snakes, whose decomposing bodies created a great stench for weeks thereafter. Yet, rainfall that day at Las Cruces 15 miles away on the western footslopes totaled only 1.93 inches, at White Sands National Monument 33 miles to the northeast only 0.87 inches, and at Orogrande 22 miles west only 1.07 inches (data supplied by Ken Kunkle, Illinois State Water Survey). Further, Kunkle (personal communication 1997) noted that the heaviest recorded daily rainfall at Las Cruces, over six inches, was not registered as significant in any other regional station.

In 1941, remembered as the wettest year of memory for most local ranchers (confirmed by records in Appendix B), a multitude of lakes formed on McGregor, some of which lasted for several years (Mr. Charlie Lee, Pete Atkins, Bill McNew, III, and Rob Cox, personal communication 1996 and 1997). Orogrande, which averages 10.1 inches, had 18.4 inches that year, followed by three slightly above normal and one below normal years. But 1941 ranks as only the eighth wettest year—15.7 inches—of the long though incomplete 147-year record (1850-1995) at El Paso, which averages only 8.7 inches per year. Seven wetter years were 1856, 1881, 1884, 1905, 1914, 1958, and 1984 with, respectively, 21.81, 18.2, 18.3, 17.8, 16.0, 17.2, and 16.2 inches at El Paso. A time series of the El Paso precipitation record between 1878 and about 1970[1] shows over 90 years of major peaks, depressions, wet periods, and dry periods (Figure 24). Interestingly, the five-year period of 1880-1884 at El Paso recorded amounts of 15.4, 18.2, 8.3, 12.9, and

[1] Pigott's graph (see Figure 24) shows the precipitation record from 1878 to 1968, which is 91 years, but his statistical n is 94(?).

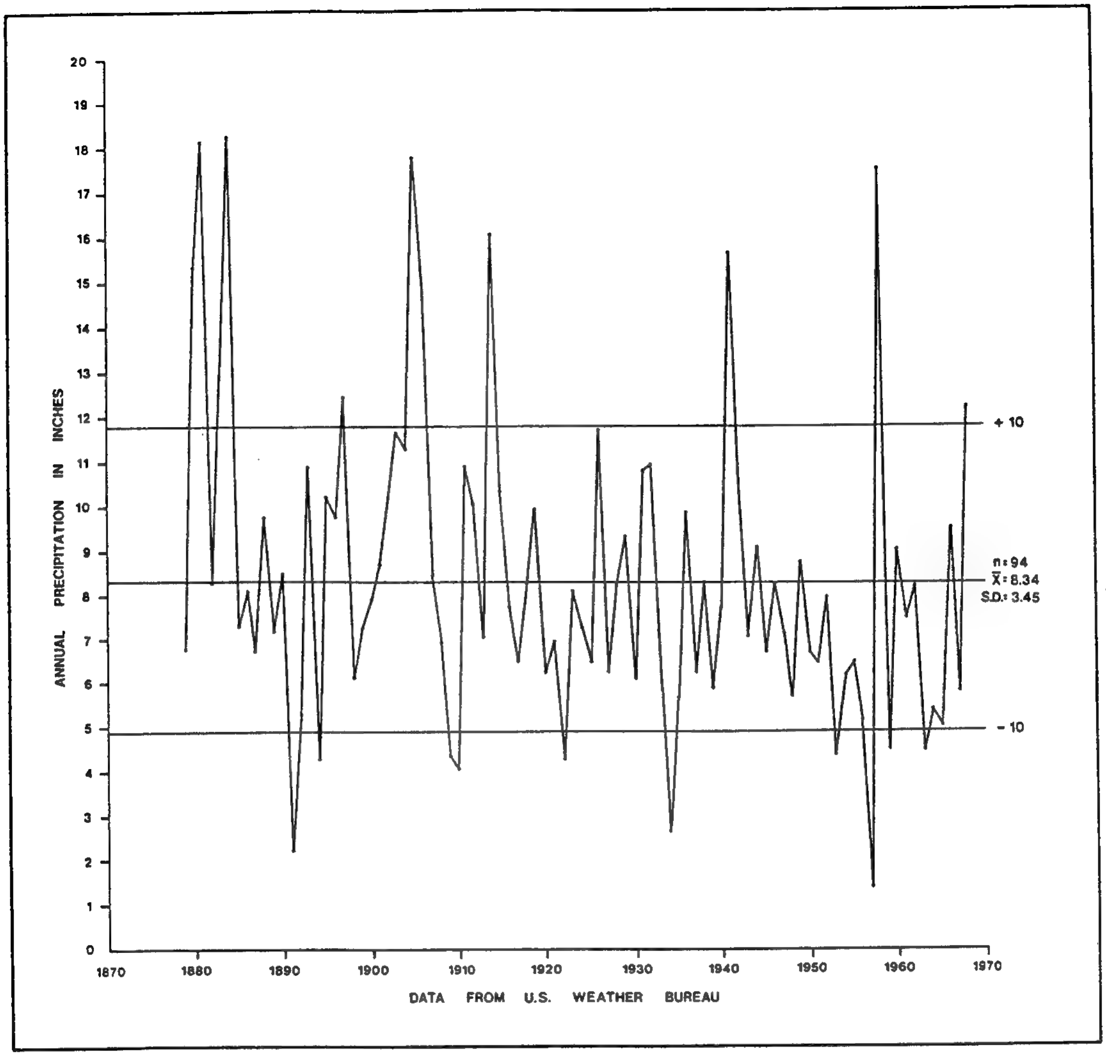


Figure 24. Time series of El Paso precipitation, from 1878 to ± 1970 (from Pigott 1977:fn 1).

18.3 inches, respectively, making it the wettest five years of record. If lakes formed on McGregor during the high rainfall year of 1941 and persisted several years, they almost certainly also formed and were larger during the much wetter five-year period of 1880-1884. They probably also persisted commensurately longer.

The data of Appendix C show that wet years are in fact not uncommon on the McGregor Range, but neither, of course, are dry ones. Wet years well over the average, with some stations approaching or surpassing 1941 in wetness, characterized 1856 and 1896 at El Paso, and at other stations including El Paso in 1904, 1905, 1914, 1919, 1926, 1931, 1958, 1972, 1986, 1990 and 1991. The years 1905 and 1914 were particularly wet across the region, as were the mid-late 1980s and early 1990s. Based on these historic records one could reasonably infer that many or most of the playas shown in Figure 25 held water, at least some water,

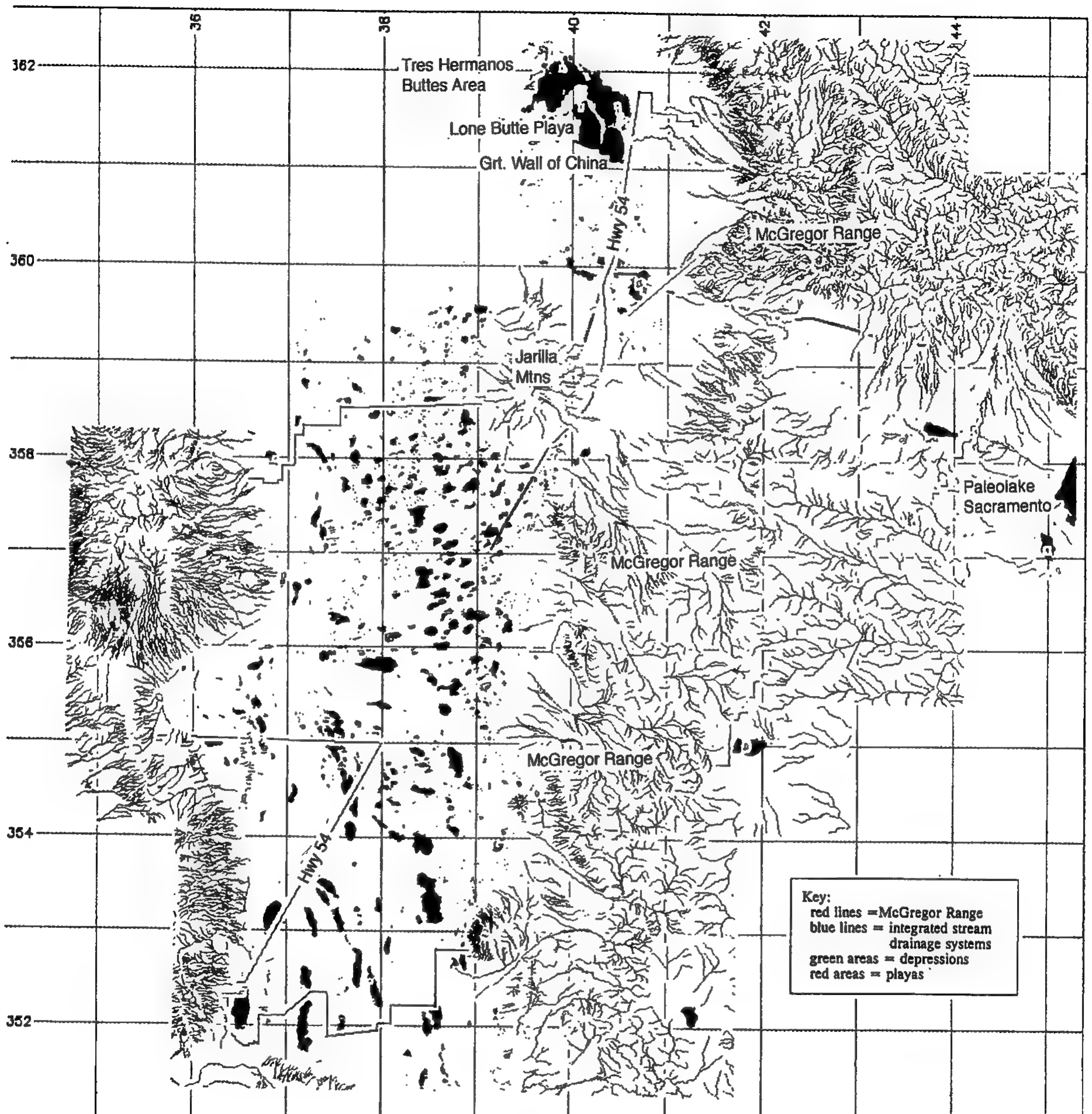


Figure 25. Raster map of drainage systems and playas of the southern Tularosa Basin and surrounding areas, including Fort Bliss and McGregor Range, southcentral New Mexico-West Texas (produced by USACERL, Champaign, IL, see text). Note playa complex around the Tres Hermanos Buttes adjacent to the northwestern tip of McGregor. Note also the very western edge of Paleolake Sacramento in the middle right (east) portion of the map (small versions of the larger Pleistocene lake have formed historically in this basin).

repeatedly for one or several years since 1850. Projected back through the Holocene, this rainfall pattern, together with plant food resources then available as documented by Kenmotsu (1977), suggests an environment that would clearly have attracted humans and other animals for sustained periods. The great abundance of fire-cracked rock and artifacts around many of McGregor's playas, and on high shorelines of some, confirms the reasonableness of this projection.

Streams and Surface Runoff

There are no permanent streams on the McGregor Range, though in early historic times the Sacramento River was close to being such before wells and diversion schemes robbed it of moisture early in the settlement history of the area (see Figure 25). The delta of the Sacramento River is a large and complex alluvial fan that debouches from the Sacramento Mountains on the northern and northeastern side of El Paso Draw. Flow was formerly to a temporary playa in the Draw south of Prather Ranch Headquarters (red playa, see Figure 25), but during wet years—or when the channel avulses—eastward flow is to a lower lying more permanent playa (large blue playa, see Figure 25). Prather Ranch headquarters is situated on the west-central side of the Sacramento Delta-fan which, according to Mr. Charlie Lee, a third generation Otero Mesa rancher (Hat Ranch), occupies the site of a large Indian encampment. The main channel of the Sacramento River presently runs down the center of the fan, but over time its distributary channels migrate across all parts of the fan (such is the nature of streams on alluvial fans). When Native American lived at the Prather site, the main channel may have been present there, possibly when the Prather Ranch was homesteaded, providing at least intermittent surface flow for both Native American and later ranchers. Projecting back in time, Native American could have lived anywhere on the fan, for perched water tables and associated springs come and go, and springs erupt unexpectedly depending on the subsurface flow conditions.

Dog Canyon, just north of McGregor Range, has a permanent spring-fed stream (Oliver Lee State Park) whose flow is immediately lost to the ground water as it debouches onto its fanhead. The role of abundant surface water as a human attractant is attested by the fact that Dog Canyon was a major habitation site for Mescalero Apache during the early historic period (Freeman 1977) and by Oliver Lee's ranch on the south toeslope of the fan.

Ephemeral streams are the rule on the McGregor Range and occur all across it. During storm periods they can become activated. Large megaboulders that not infrequently occur at midslope fan positions are testimony to the episodic energy that is released at such times. However, most stream channels on McGregor also have been fitted with tanks and stock ponds designed to trap water before it is absorbed into the stream bed or reaches the alluvial fan onto which it debouches—or before it reaches a playa. Some streams have multiple tanks. In fact, there are innumerable tanks on the McGregor Range, and each has played a role, perhaps a greatly underappreciated role, in the changed water ecology in postsettlement times.

While fully acknowledging that stock tanks are necessary for ranching activities in the Southwest and that such tanks have probably saved many a rancher from bankruptcy, the cost to the local and regional ecology could be high and might warrant careful consideration in management strategies in a unique, grazing controlled situation like McGregor. Runoff that would normally filter into the substrate and recharge local water tables over a large area is robbed by tanks. While tank water is utilized by animals, wild and domestic, much also evaporates. This represents water lost to recharge and resupplying downslope seeps, miniwetlands, vegetation, and springs. Springs and seeps ecologically redistribute rainfall far more efficiently over time than do artificial ponds, which waste environmental water through evaporation and by not contributing to moist spots successions of biota. Consequently, precipitation totals in tank-developed areas can, environmentally speaking, be misleading. The role of tanks and waterwell drawdowns as underappreciated robbers of environmental water may be the source of the generally perceived droughtiness that is lamented by almost all the ranchers (Atkins, Cox, Lee, McNew, and Holcomb) interviewed in this study.

Springs

Springs are surprisingly rare on McGregor Range proper but are common in surrounding upland areas and may once have been more widespread in presettlement time (see above). Culp Spring occurs on the McGregor reservation at the old Marcus Quick place one mile north of County Road 506 on the grade up to Otero Mesa (Culp Canyon quad) (Figure 26). When visited in 1996 it held a pool of potable water and displayed abundant signs of regular wildlife use. Water here was said to be present in 1975, but not in 1917 (Freeman 1977). Possibly, it may dry up during long drought periods. According to Mr. Charlie Lee, proprietor of Hat Ranch on Otero Mesa and grandson of pioneer settler Oliver Lee, a spring seep was rumored to occur, or once did occur, in Martin Canyon several miles east of Little Mack Tanks (Otero Mesa S quad). The rumor was confirmed by Mr. Pete Atkins, who once tried to find it but failed. Atkins also shared a rumor with the author that he attributed to "old-timers" who told of a spring seep in Rough Canyon, which he (Atkins) has been unable to confirm.

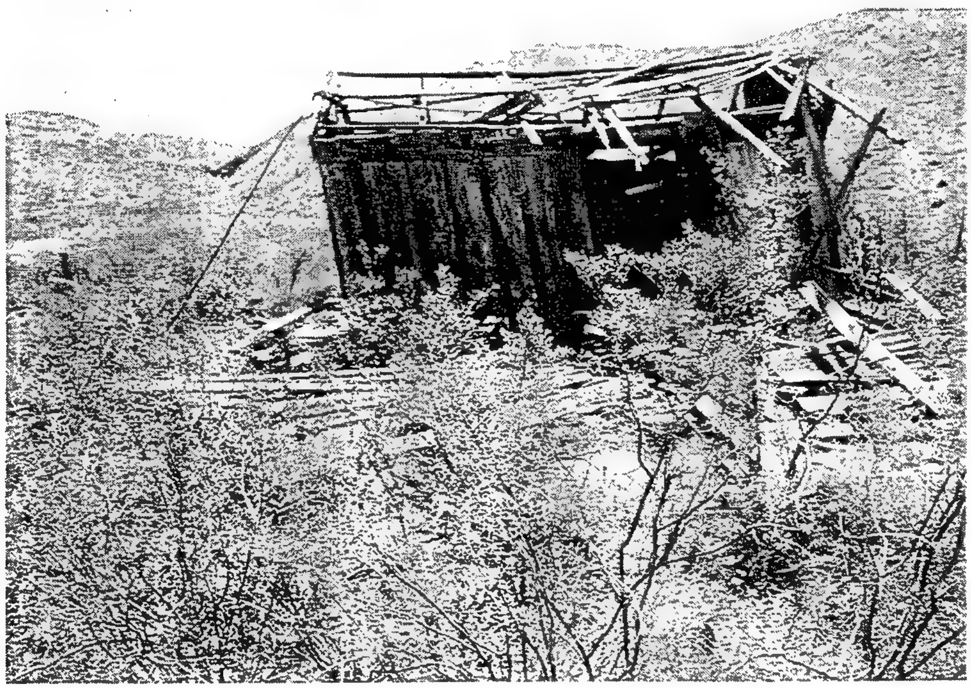


Figure 26. View of the old Marcus Quick place—the location of Culp Spring—situated one mile north of County Road 506 on the grade up to Otero Mesa (photo taken in 1996, looking east-northeast; Culp Canyon quad).

The southern Sacramento Mountains, in addition to the intermittent Sacramento River water supply, contain numerous springs and seeps. On the Rogers Ruins quad (and on the 2-DMATC ser. V781 1:50,000 Maps, Sheet 4748 IV, Rogers Ruins) in the Sacramento drainage, these springs include Bear, McEwan, Bear Wallow, Monument, Sulphur, Jim Lewis, and Barrel, as well as the exceptionally copious Carrisa Spring. On the Bug Scuffle quad, the Grapevine Canyon drainage includes Wild Boy, Grapevine Canyon, Wright, and Little Cherry springs, and Dripping Spring near the mouth of Escondido Canyon. A spring also occurs near the mouth of Negro Ed Canyon just off McGregor on the Bug Scuffle Canyon quad that, according to Pete Atkins (personal communication 1996), produced five gallons per minute when measured. Laney Spring is on the lower Pack Trail between Escondido and Deadman canyons, Lawson Springs just south of Dog Canyon, and several copious springs flow at Dog Canyon creating permanent streamflow there (all three springs are on Deadman Canyon quad).

A spring seep also occurs in Water Canyon (see Figure 15), appropriately named, on the east side of the Jarilla Mountains (Orogrande N quad) which, according to Orogrande lore, was used by Native American. When visited in 1996 it had been dug out and collared with railroad ties and contained a pool of water. Downstream near the mouth of Water Canyon, a well was recently (ca. 1994) drilled to a depth of 580 ft and supplies eight gallons per minute to a nearby tank which supports a stock pond (Mr. Earl Johnson, personal communication 1997). According to Bill McNew, III (personal communication 1997), a German immigrant family headed by "Mr. Alsdorf" built a house next to the spring in Water Canyon and lived there from the late 1910s to the 1930s, using water from it for domestic use and for maintaining a few animals (the house remains are still visible). In light of the historic reliability of this spring as a water source, it doubtless served as a source of water in prehistoric time as well. The significance of the spring to this report is that it is very near McGregor Range and probably played some role in sustaining aboriginal and wildlife activity in the Jarilla Bolson part of McGregor.

Several springs occur just south of McGregor in the Hueco Mountains, several on the north side of Cerro Alto that are used for wildlife watering (Mr. Pete Atkins, personal communication 1996). Nearby Hueco Tanks was an important and well-known aboriginal and historic watering place. Another important spring that Native American used was near the base of Alamo Mountain, the westernmost of the Cornudas Mountains (Mr. Charlie Lee, personal communication 1996). At least one other spring is (was) present historically in the Cornudas, as described by Black (1973).

On the other side of Tularosa Basin are the Rio Grande surface waters, the Franklin Mountains with various springs, and the Organ Mountains with numerous springs and seeps. The latter, of course, face the Tularosa Basin and include Dripping, Soledad, and Globe springs (in Soledad, Pete Johnson, and Texas canyons); Pine Spring in Rucker Canyon; Aguire, Spirit, and San Augustine (Cox Ranch) springs near White Sands Missile Range Headquarters; and Alamo, Bennett, San Juan, and San Nicolas springs farther north (Freeman 1981; Kelley 1975; Meinzer and Hare 1915; 2-DMATC ser. V781 1:50,000 Maps, Sheets 4748 IV and 4749-III, White Sands and Lake Lucero).

According to Martha Doty Freeman (personal communication 1997), who produced settlement histories of Doña Ana and McGregor ranges (Freeman 1977, 1981), the basinal area southwest and northwest of Newman and west of McGregor had several early pioneer settlements, and water was present, apparently as either seeps or a high water table accessible by hand dug wells (well drilling technology was just then becoming available to these ranchers). The area has numerous en echelon normal faults and associated down-dropped blocks, some with evidence of periodic ponding or wet weather ponds and lakes. So seeps and/or periodic ponds may then have been present in the area, or episodically present depending on rainfall patterns.

The area north of the Tres Hermanos has a number of springs that issue from a shallow water table, often under artesian pressure. Some of the springs are mounded, partly owing to coppicing, and are called 'spring mounds' by Meinzer and Hare (1915) who counted 29 of them in the central Tularosa Basin. The water they yield is generally alkaline, but obvious evidence of heavy wildlife traffic around some of them indicates that animals regularly use certain ones for watering (personal observations 1996). One of the largest of the spring mounds is the site of the Sally Walker Ranch (formerly White Sands Ranch, G. V. Oliver Ranch), four miles east of Point of Sands on Hwy 70, three miles north-northwest of Twin Buttes. Another spring is at Point of Sands along Hwy 70, where water is (or was in 1911) eight feet from the surface and marginally drinkable, though people drank it and stock used it (Meinzer and Hare 1915:260). Another is Black Spring on the Jobe Quarry Cement holding on the north side of Highway 70, opposite the north gate entrance to the Sally Walker Ranch. When visited in 1996 it was flowing and had many ungulate signs (defecate, trails radiating from it), and at least one other moribund spring mound was observed nearby. Water from the flowing spring tasted poorly. During this visit Jobe Quarry personnel had inadvertently just broken into an artesian head several feet deep next to a limestone bedrock protrusion near Black Spring. The water tasted fair, but otherwise its quality was undetermined.

Several miles southeast of the White Sands National Monument headquarters, beyond the limestone hill which contains its water tower, is a pond now called Garton Pond (Nancy Wizner, Chief Ranger, WSNM, personal communication 1996). Mr. Charlie Lee recalled swimming in the pond, created when a drilled artesian well overflowed, when he was a child (at which time it was called the Old Sheppard Place). When visited in 1996 stands of salt cedar and cattails (*Typha*) were present, and grass cover was fairly extensive. According to Wizner, the pond had once been used as a natural environmental study area for students and local groups. The quality of the water was not ascertained, but the effloresced soil in the area suggested that it was nonpotable or marginally potable for humans, but apparently not for wildlife since signs of wildlife were present.

One would suspect that inasmuch as limestone (Permian Yeso and San Andres formations) forms and underlies Otero Mesa, and inasmuch as its surface is karstic, at least in its central and eastern portions, that springs would be common at the base of its west escarpment facing the Tularosa Basin. Such expectations would almost surely be realized were it not for the fact that the general dip of the limestone is east. Consequently, and unfortunately for local wildlife and humans, ground water and most surface water drains east, away from the Tularosa Basin. Any springs that might exist along the escarpment would either be small, or require special geologic circumstances.

Water Table Levels and Water Quality

Around and north of Tres Hermanos the water table is under artesian head (e.g., well springs at Black Spring, Garton Pond and south of it, various spring mounds). In an old six-inch steel wellhead on the southeast side of Prospect Butte (the 'Fourth Hermano'), 1.3 miles northeast of Twin Buttes (at the Jobe Quarry cement prospect), a dropped pebble hit water in 2.2 seconds (its quality undetermined). At Lone Butte Playa and Great Wall of China Playa, the water table is within capillary flow of the surface (6 to 8 ft) and is alkaline such that it precipitates salts at the surface, which wind then removes. According to Roy Holcomb (personal communication 1996), when Swope Tank in Lone Butte Playa was bulldozed out, the ground water was so bad that a clay liner was installed to keep it from ruining the stormflow water, which the tank was dug to collect. According to Bill McNew, III (personal communication 1997), the former owner of Great Wall of China Playa, Hugh Longwell, once dug a tank in its floor with a scraper pulled by four horses, which filled with ground water. The horses drank from it and died, as did birds and other animals, later. From then on the locals called it "Poison Well Lake." In sum, springs and playas in the artesian flow area are located along and around the bedrock ridge that extends north from the Jarillas beyond the Tres Hermanos and into the White Sands dunefields. Water from these sources ranges from being fit for animals and marginally fit for humans, to being poisonous to all.

The water table north of McGregor Range is relatively high near Dog Canyon but gradually drops to the south into the Jarilla Bolson, and even more so south of the Jarillas. Water quality follows the same trend. At a well located 0.3 miles south of Dog Canyon Road and 0.8 miles east of Hwy 54, the water table is said to be 200 ft deep and potable (unidentified owner of property, personal communication 1996). Several miles farther south at 141 Roberts Road depth to water in a 150-foot deep well is 80 ft (Connie Roberts, property owner, personal communication 1996).

According to Meinzer and Hare (1915:258), the depth of Cox Well (formerly Lee Ranch, McNew Ranch) in 1911 was "130 feet and yields water of good quality." According to Pete Atkins (personal communication 1996) the well is now 350 ft deep and produces water of good quality. Several miles farther south-southwest at Salt Cedar Playa, a perched water table probably is present as suggested by the salt cedar shrubs that grow there (though they appear stressed). Wilde Well, 4.5 miles south, in 1911 was said to be 526 ft deep with a water level 244 ft below the surface (Meinzer and Hare, 1915:253). Benton Well, several miles farther south, according to Mr. Atkins, is 450 ft deep and 407 ft to water.

Considerations of Water Quality

Potable water in the U.S. is defined as having less than 250 parts per million of dissolved salt (Knowles and Kennedy 1958; McLean 1970a, 1970b, 1975; Meinzer and Hare 1915). That quantitative measure, however, defines a standard of tolerance that relates to *present* societal preferences, not necessarily to presettlement preferences of Native Americans. Nor does it relate to tolerances of stock animals or wildlife. Taste and illness-health considerations must, in the final instance, set the tolerance limits for wildlife, for stockmen tending their stock, and for presettlement Americans. Oral traditions must have been one determinant for Native Americans ("don't drink from *that* spring"). The water quality of the artesian springs and ground water north of the Jarillas, for example, varies widely, ranging from drinkable though nonpotable for modern humans (Point of Sands Spring), to drinkable for animals but marginal to undrinkable for humans (Black Springs), to undrinkable and toxic (ground water at Lone Butte Playa and Great Wall of China [Poison Well] Playa).

Other things equal, when a playa receives runoff its water quality must then be highest (least dissolved salts), then decrease as evaporation of the temporary lake proceeds. The greater the volume of the lake the higher is the quality of water, again other things equal. Moreover, each playa in a playa-rich area like McGregor should, theoretically, have a unique salt signature per volume of water present. These signatures might even vary with time depending on meteorological conditions, the changing chemistry of rocks exposed by weathering and erosion, and so on. Evaporation periods would be different for each lake because of surface area/volume differences, wind velocity differences, etc. Some may be drinkable even during their last stages of evaporation, whereas others may not. The point is that each playa lake will, theoretically, have a different level of drinkableness from its full to nearly evaporated stage, and therefore generalizations across the board can not be made about the past drinkableness of playa lakes on McGregor Range.

Playas and Temporary Lakes

Definitions

A playa is defined as "an intracontinental basin where the water balance of the lake (all sources of precipitation, surface-water flow, and groundwater flow minus evaporation and evapotranspiration) is negative for more than half the year, and the annual water balance is also negative" (Rosen 1994). The playas of the southern Tularosa Basin and surrounding lands, including most playas in New Mexico, function as periodic temporary lakes, which also holds true for McGregor Range (see Figure 25). Playas may be either *temporary,* those subject to breaching and or overflow into lower lying land, or *permanent*, those that occupy the lowest part of the land and do not overflow. Technically speaking, Lake Lucero is the only truly permanent playa in the Tularosa Basin drainage area, for all others would theoretically fill and overflow into it if regional rainfall significantly increased, as apparently was the case during the last glacial-pluvial. But in the absence of such rainfall amounts during the historic period, several near-permanent playas are recognized on the McGregor Range. Most notable are Salt Cedar Playa in the Jarilla Depression, and Alvarado Tank No. 1, Snail, Vertisol, Lake Tank, and Fault Line playas as well as several others in the McGregor Range Camp area.

Genetic Types

Permanent and temporary playas may be genetically classified as follows, though none are mutually exclusive (i.e., multiple genetic processes often form and/or impact a given playa):

1. *Solutional (karst) playas* (e.g., Bassett Lake and numerous other limestone playas on Otero Mesa, especially east of McGregor Range, Stone Well quad)

2. *Deflation playas* that have genetically associated downwind lunette dunes (e.g., Cox Well Playa in the Jarilla Bolson, and many playas northwest of Three Buttes near the McGregor Range Camp area)
3. *Dune-dammed playas*, ephemeral and historic (e.g., Benton Well and Wilde playas, each historic in age and buttressed by dune trains)
4. *Dunal playas* (e.g., any dunal depression that temporarily ponds water; extremely ephemeral)
5. *Evaporation-precipitation-deflation (salina type) playas* that have genetically associated downwind lunette dunes (e.g., Lake Lucero, Great Wall of China, Lone Butte playas)
6. *Faultline playas* (e.g., Faultline and Lake Tank Playa southeast of Davis Dome)
7. *Porous (leak-through) playas* (e.g., Meyer Range Road Playa)

The first four playa types above are self evident, but the latter three warrant further discussion. As mentioned, evaporation-precipitation-deflation playas are those with fluctuating and minerally charged water tables, sometimes just below the playa floor, and from which capillary flow to the surface occurs. Dissolved salts precipitate at the surface as ground water evaporates, producing surface efflorescences of alkali salts (halite [NaCl], gypsum [$CaSO_4 \cdot 2H_2O$], epsom salt [$MgSO_4$]). Wind gusts erode and saltate these salts downwind to form alkali lunettes. The process slowly lowers the floor of the playa. Since water tables fluctuate through time, high water tables may cause the playa to flood for periods with briney ground water. Runoff water during wet periods can also flood these playas. Examples of these genetically complex salina-type playas are west, north, and east of (i.e., all around) the Tres Hermanos Buttes (e.g., Lone Butte and Great Wall of China playas, plus others unnamed). U.S. Highway 70 passes through several of these salina-type playas between Alamagordo and Point of Sands. Lake Lucero is, in fact, a classic example.

Faultline playas form in faulted terrains and thus are often linear or sublinear in shape reflecting the orientations of the faults that produce them. Multiple normal faults can produce downdropped en echelon segments, and playas and wet weather lakes form in them. Figure 27 shows a large number of faultline playas in part of Fort Bliss, and 1:24,000 scale air photos show many more around Newman, including many in the basinal southwestern part of McGregor Range. In fact, Figure 27, the air photos, and the Landsat photos of Figures 1 and 2 show that many of the playas of the Tularosa Basin are initiated as faultline playas. Wind deflation may, and often does, subsequently modify them.

Porous (leak-through) playas occur in some depressions on the basinal La Mesa surface, and water that collects in them apparently drains downward as recharge water into the Camp Rice gravels and sands. The playas have very limited catchment areas, which may explain why their playa sediments are thin and their soils less well-developed than surrounding Doña Ana soils. The southwestern part of basinal McGregor has several such playas.

It is worth stating again that none of these genetic playas are mutually exclusive, and some in fact, if not most, are polygenetic. Some of the faultline playas on the La Mesa surface in the southwest basinal part of McGregor Range, for example, are also porous (leak through) playas. Some of the evaporation-precipitation-deflation (salina type) playas that typify the Tres Hermanos area are probably also faultline playas, and they also receive surface runoff.

Although not shown in the genetic categories above but probably very important on the McGregor Range and Tularosa Basin playas is the role of large wallowing animals. It has been shown in Africa, for example, that when wallowing animals leave ephemeral, gradually drying lakes (playas) and water holes, they remove considerable lake sediment on their bodies as mud (Davison 1967; Weir 1960). Over time playas can significantly deepen by this biotic method, which is independent of wind, faulting, etc. Many of the African pans are believed to have been formed in this fashion.

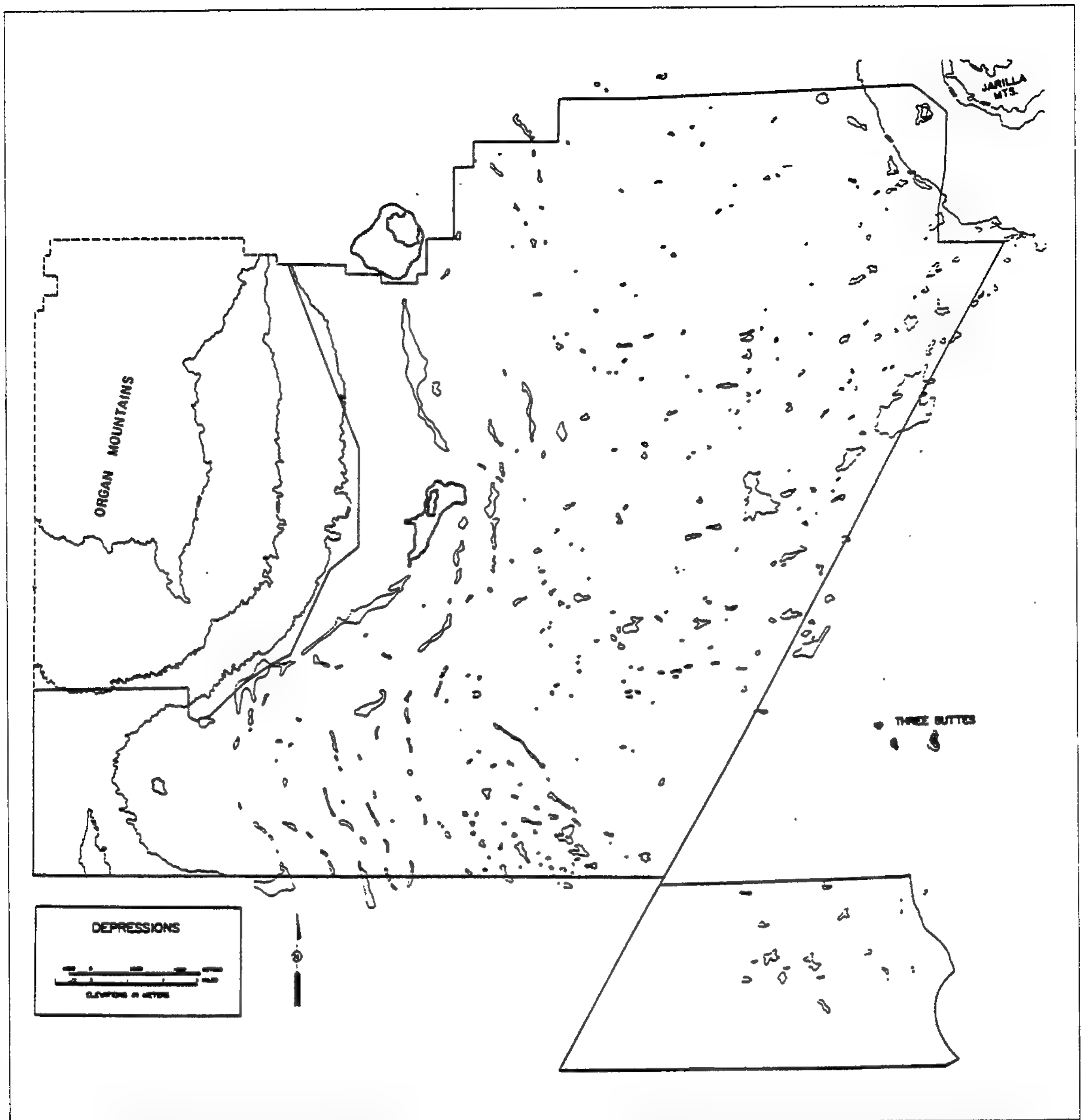


Figure 27. Closed depressions containing playas in Fort Bliss Maneuver Areas 3-8 (after Carmichael 1983). Note that most depressions on the western half of the map are linear and form an arcuate pattern, reflecting the faulting pattern of the area.

Geoarcheologic and Geoecologic Importance of Playas

All seven genetic types are present on McGregor, and each periodically contains water and thus attracts animals and humans. Because many of the McGregor playas were observed to contain artifacts, fire-cracked rock, and other relics of prehistoric humans, and because each plays important ecological roles in the McGregor environment, albeit episodically, they are given expanded attention here.

Wet Weather (Temporary) Playa Lakes

Other than some stock ponds, there are no permanent lakes on the McGregor Range, but there are innumerable so-called wet weather lakes, or temporary playa lakes. They form episodically, either during exceptional storms or during wet periods, as local historic records confirm. Freeman (1977:117), for example, noted that around 1895-1896 the McGregor pioneer Fleck family lived near Newman until "a lake flooded their house," causing them to move. On June 30, 1995, a downpour over the Jarillas created a lake in a depression alongside Highway 54 several miles south of Orogrande (Pat Johnson, Orogrande weather recorder, personal communication 1996). Most of the ranchers interviewed in this study recalled seeing lakes from time to time on McGregor, and the climatic record clearly indicates that this is the case.

As indicated, Figure 25 shows all the temporary lakes and playas in and around the southern Tularosa Basin, plus a few on Otero Mesa, including the western edge of Lake Sacramento playa (right, east side of map). Figure 28 shows modern drainage and paleodrainage of the southern Tularosa Basin.[2] It shows that during big storms and wet years, and during similar times in the late Quaternary, the general direction of flow is into two depressions: (1) the linear Otero Depression along the west side of the Tularosa Basin at the foot of the Organ and San Andres mountains, and (2) the Jarilla Depression east and northeast of the Jarilla Mountains. Presently the Otero Depression contains an unintegrated array of dry lakes, Old Coe Lake on the south, followed by Davies, Parker, White Ranch, No Name, and Lucero lakes to the north (all were dry playas in the fall of 1995 and spring of 1996; see Figure 2). The lowest part of the Jarilla Depression contains several miniplayas, most unnamed, the lowest of which is Salt Cedar Playa whose floor is at 3,988 ft (1,216 m) elevation (Orogrande N quad). During wet periods, waters in these playas coalesce and form two lakes, one centered at the latter playa, another centered three miles to the northeast at Cox Playa (Cox Well). Slightly high ground that is clogged with dune piles and lunettes presently separates them, but during exceptionally wet periods, or when dunes migrate so as to create channelways, they coalesce and form a combined larger lake. The elevation of the floor of the upper playa at Cox Well averages about 4,015 ft (1,224 m), while the lower one at Salt Cedar Playa averages 4,000 ft, with its central depression at 3,988 ft. These combined playas are here called Jarilla Playa. Any temporary lake that forms in it would be called Lake Jarilla. Because dune piles that slowly migrate northward across it as dune trains lie some 15-30 ft higher, they would protrude above any shallow lake that formed.

In 1941 two shallow lakes did form in the Jarilla Playa (Pete Atkins, Charlie Lee, Bill McNew, III, personal communication 1996, 1997). According to Atkins and McNew, Mr. Tom Bell, who owned the property at Cox Well on the playa had his holdings flooded, including his house which was near the well, by the northern lake. McNew estimated this lake to be about two miles long (north-south) and a mile or so wide. According to McNew, Bell's cattle tank contained goldfish, put there either to keep algae under control as McNew thought, or possibly put there by ranch kids as suggested by Charlie Lee. When the playa flooded, the goldfish apparently escaped into the lake and reproduced prodigiously, for when the lake dried up several years later, dying goldfish that numbered in the "tens of thousands," according to McNew, littered its shores. Some had grown to "a foot or more in size," and upon dying created "a terrible stink for many weeks." The

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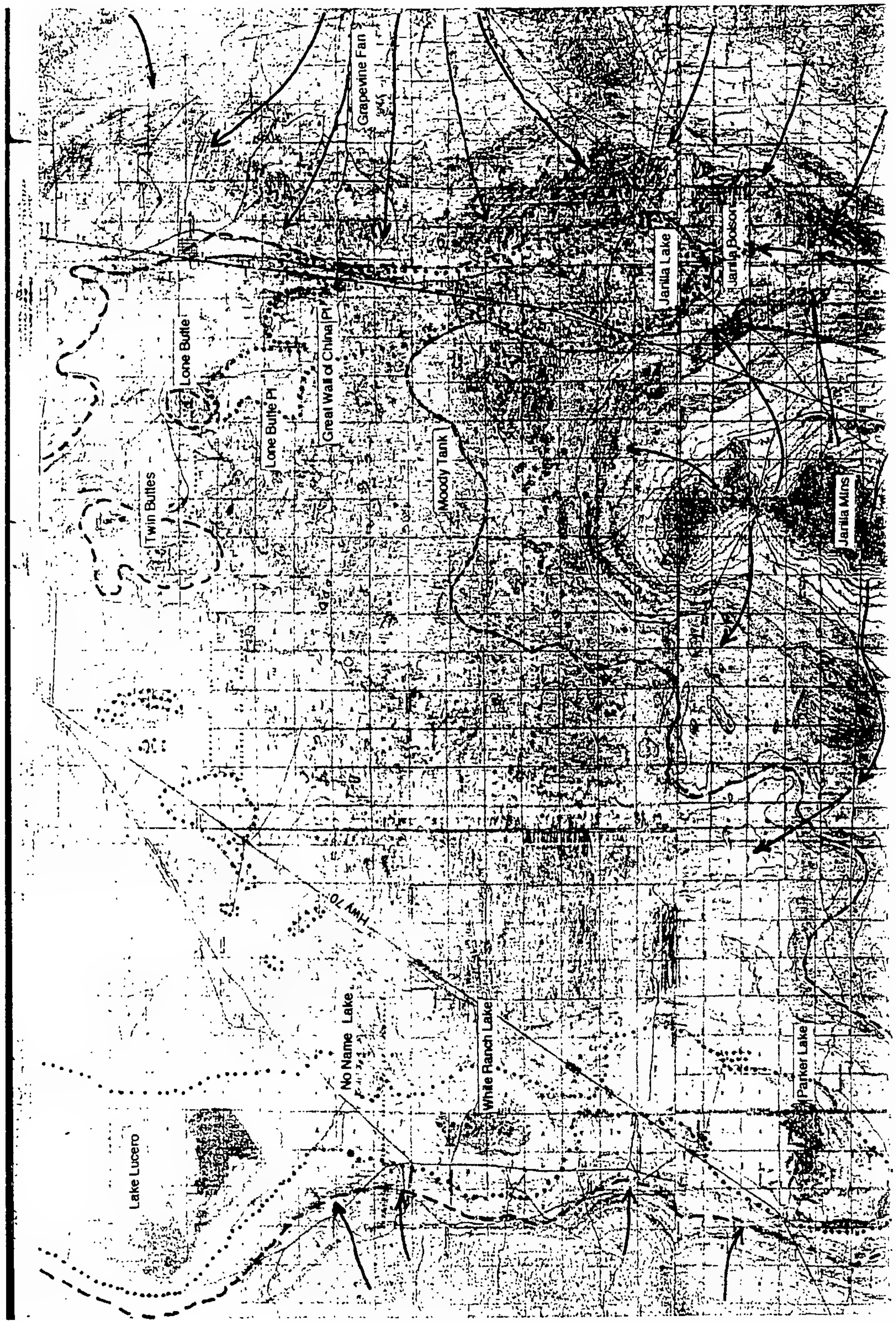
[2] The dashed line in Figure 28 shows the inferred extent of the high version of Lake Otero at 4,010 ft (1,222 m) similar to Herrick's 1904 model, while the dotted lines defining Parker, White Ranch, No Name, and Lucero lakes show the inferred extent of the low version (3,950 ft, 1,204 m) of Lake Otero similar to Hawley's 1993 model.

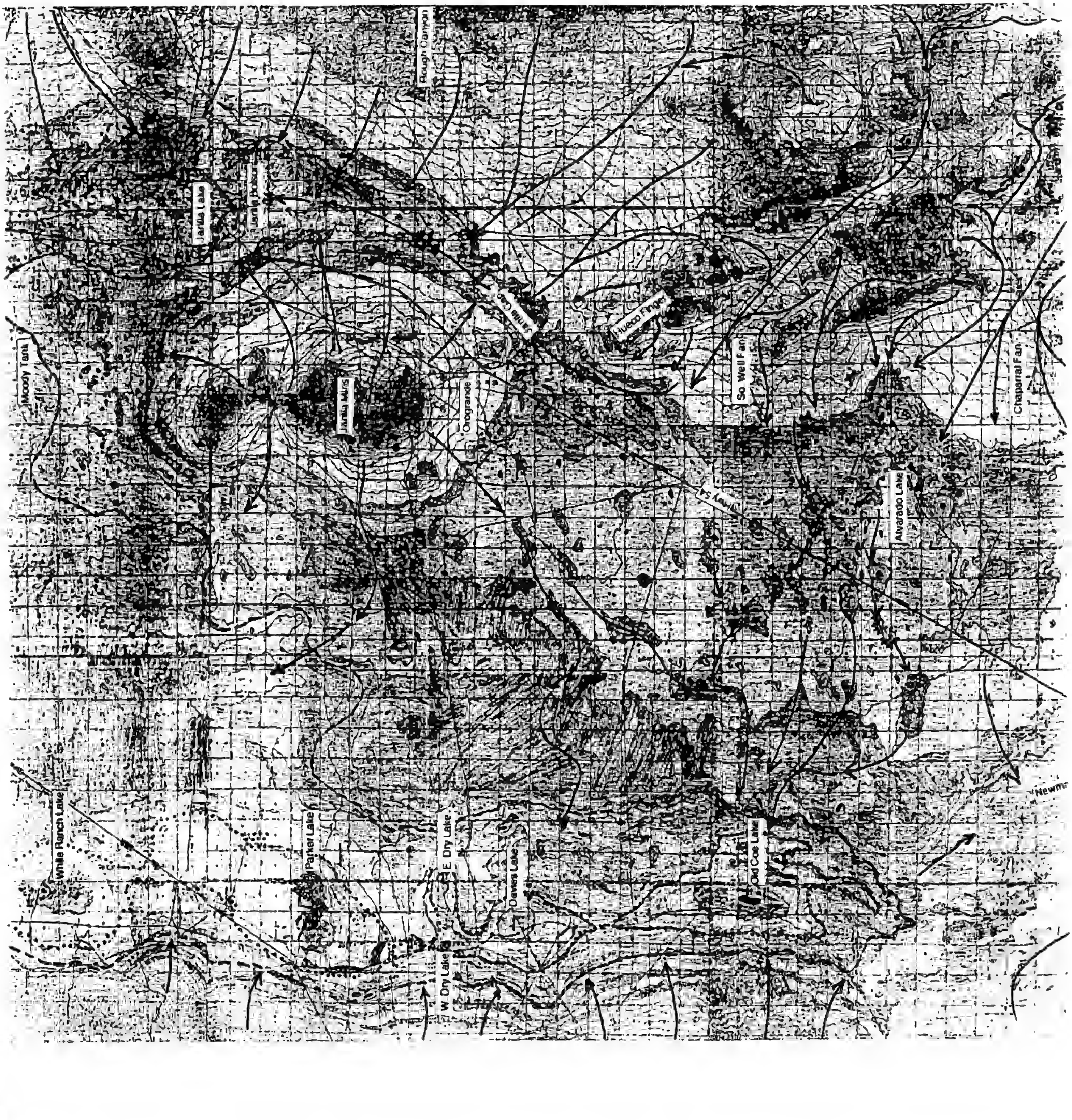
Dotted lines around Old Coe and Davies lakes are, respectively, at 3,966 and 3,957 ft (1,209 and 1,206 m) elevations, which would be their high levels if the low version of Lake Otero is valid (at 3,950 ft). They respectively would have elevational drops (sills) at their northern ends of 11 and 7 ft before entering low Lake Otero at the 3,950-ft level. Dotted line around Lake Jarilla is at 4,010 ft if the low (Hawley's) version of Lake Otero is valid. If the high (Herrrick's) version proves valid, then Lake Jarilla and the northwestern part of McGregor would have been part of Paleolake Otero, as indicated by the dashed line.

Dotted lines around Alvarado, Faultline, and Lake Tank lakes, and other small lakes in the area are inferred on the basis of modern flood histories, and on depressional contours on the map. (See text for further discussion.)



Grapevine Fan
Jarilla Lake
Jarilla Bolson
Lone Butte
Great Wall of China Pl
Lone Butte Pl
Moody Tank
Twin Buttes
Jarilla Mtns
Hwy 70
No Name Lake
White Ranch Lake
Parker Lake
Lake Lucero

1



Rough Canyon
Moody Tank
Hueco Finger
So. Well Fan
Chaparral Fan
Orogrande
Alvarado Lake
White Ranch Lake
Parker Lake
E. Dry Lake
W. Dry Lake
Old Coe Lake

3

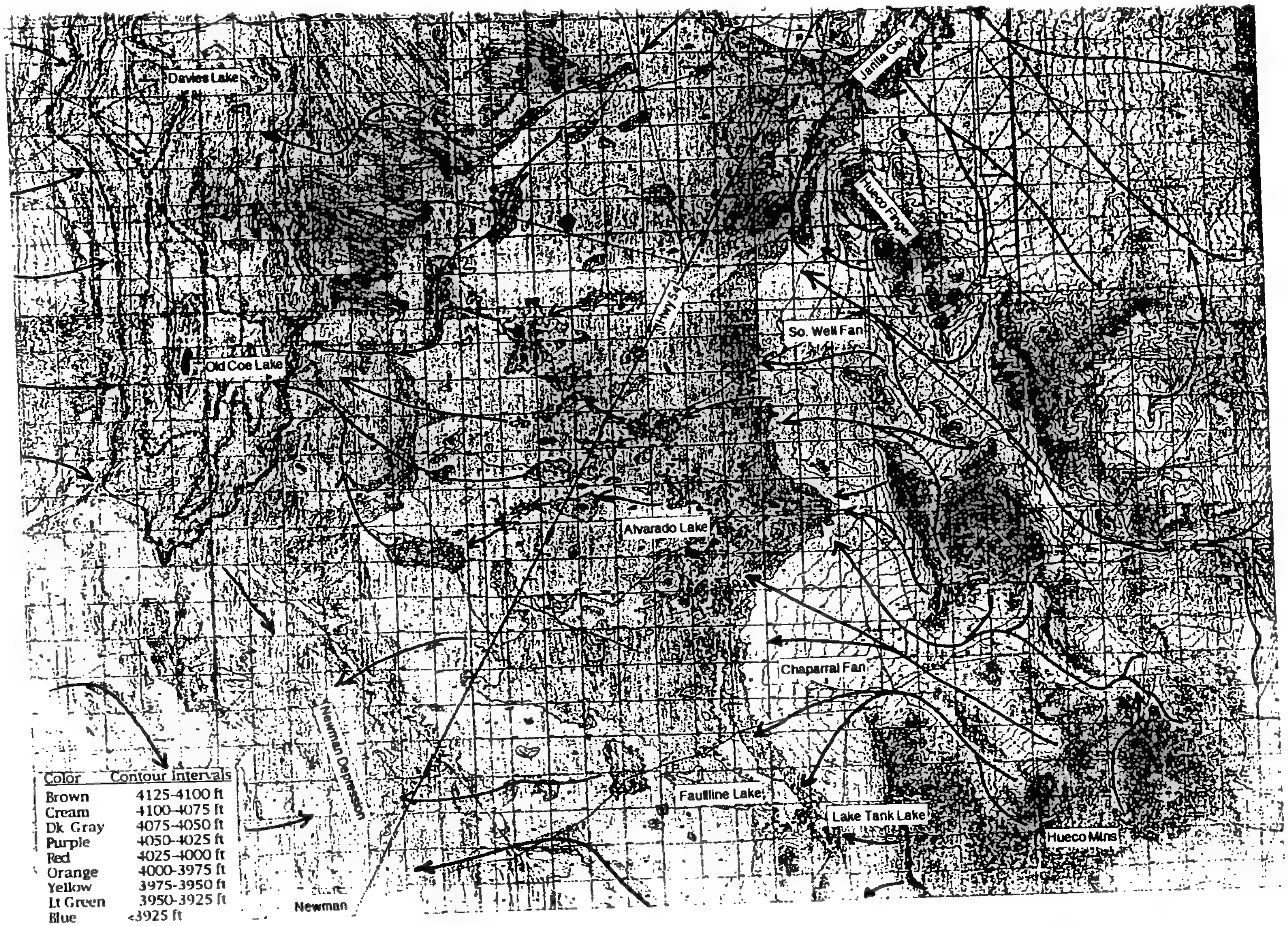


Figure 28. Modern and pluvial (12-22ka years ago) lakes (dashed and dotted lines) and modern and paleodrainage (arrows), southern Tularosa Basin. Dashed line shows the inferred extent of the high version of Lake Otero at 4,010 ft (1,222 m) elevation, whereas dotted lines around Parker, White Ranch, No Name, and Lucero lakes show the inferred extent of the low version of Lake Otero at 3,950 ft (1,204 m) elevation. Map was produced from multiple USGS 15 minute topographic quadrangle maps, with shaded contour intervals as indicated in legend.

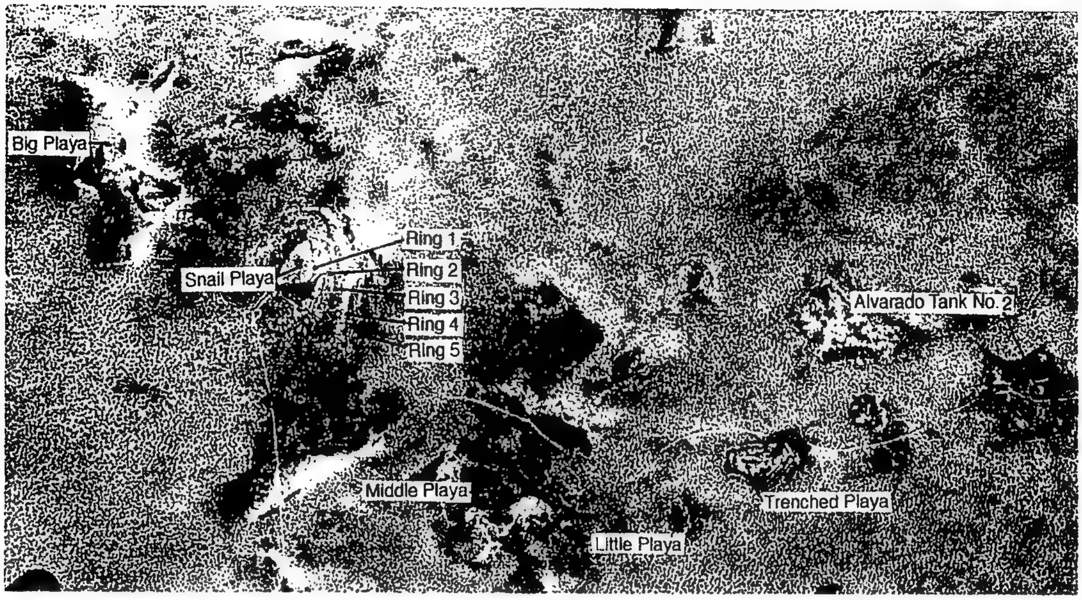
point of this narrative, aside from its interest, is that no firm records exist about how long Lake Jarilla persisted after it reformed in the early 1940s other than the collective recollections of ranchers Atkins, Lee, and McNew (Atkins and Lee thought it persisted for "a year, possibly two," but McNew said "three to four years"). The goldfish saga confirms that the lake existed long enough—possibly three to four years, as McNew thought—for goldfish to multiply in great numbers and attain large size.

According to Mr. Rob Cox, longtime proprietor of San Augustine (Cox) ranch near White Sands Missile Range headquarters, in 1941 large lakes formed in Old Coe, Davies, Parker, White Ranch, and Lucero playas. (Like the other ranchers interviewed in this study, Cox is a descendant of a well-known pioneer family, e.g., Cox Well, Cox ranch, etc.) How big the lakes were and how long they persisted before drying was not determined, but, according to Cox, some of these playas have periodically held lakes since 1941.

Mr. Charlie Lee recalls that several times water flooded John O. Flat near the La Heeta Harvey (Stevens) ranch along the eastern toeslopes of the Sacramento River fan (Cleones Tank quad, 105° 30'W, 32° 15'N; see Figures 1, 6, and 25). This large lakebed, whose central playa is 4,288 ft in elevation, is the terminus of the Sacramento River during high flow periods. Pearl Lewis (personal communication 1997), a Prather family member and lifelong resident of Otero Mesa in the Prather ranch-John O. Flat area, recalls the Sacramento River flowing into the Flat several times during and since the 1940s. During the late 1940s, "when her two sons were toddlers" (born in 1945 and 1946), the Sacramento River flowed uninterrupted for several weeks, blocking her family's access to certain tracts, and flooding John O. Flats to the extent that it flooded Lower Tank (and well) and almost flooded the Stevens ranch headquarters (both on the Cleones Tank quad). The headquarters is 2.5 miles from the central playa and 10 ft above it, the elevations of the former being 4,298 ft, and the latter being 4,288 ft. Though the lake would have been shallow it would have measured more than four miles in diameter. During this incident the lake probably formed either during July-August 1949, or July 1950, both wet months and years in the Sacramento Mountains (cf., Cloudcroft, Lulu, and Mayhill records, Appendix B). If lakes formed on the Flat several times during her life as she recalls, and one formed in 1949 or 1950, then a much larger one must have formed in 1941, by far the wettest year of record for all stations. If the various wells and water diversion schemes that have historically intercepted most of the Sacramento River and its subsurface waters had never been installed, Lake Sacramento probably would still now periodically form.

During the 1940s storms, many other lakes formed on the McGregor Range and elsewhere in the Tularosa Basin. According to Atkins, a lake estimated to be a mile in diameter formed north of Three Buttes near McGregor Base Camp in 1941. This would have included the large depression at Alvarado Tank No. 1 as well as the Paternoster playas that include West Butte, Linear, and Snail playas, and several other nearby unnamed playas (Desert quad). Another lake formed in the north-south fault depression just below the escarpment east of Davis Dome, and another formed in Lake Tank. In fact, several 'bathtub rings' can be discerned around Lake Tank, Snail Playa, and Vertisol Playa on various air photos used in this study (Figure 29). The largest ring around Lake Tank indicates a mile-long lake formed, probably in 1941, but also probably at other wet periods as well (see Figure 24). Smaller rings indicate periodic smaller lakes, probably formed since—at least formed so recently that new in-washed sediment has not obscured them). Bathtub rings around Snail Playa where locally not obscured by dunes also indicate periodic sizable lakes, almost certainly linked to the same wet years that produced the rings of Lake Tank (see Figure 29).

An important point to remember is that evidence for historic temporary lakes in the Tularosa Basin portion of McGregor, whose existence is proved by early 1940s observations of ranchers at Cox Well, Lake Tank and Alvarado Tanks, and by bathtub rings around Lake Tank, and Snail playas, would doubtless be apparent around most McGregor playas if it were not for obfuscating dunes. The abundance of surface archeological sites, artifacts, and fire-cracked rock in and around Vertisol Playa, Snail Playa, West Butte Playa, the Great



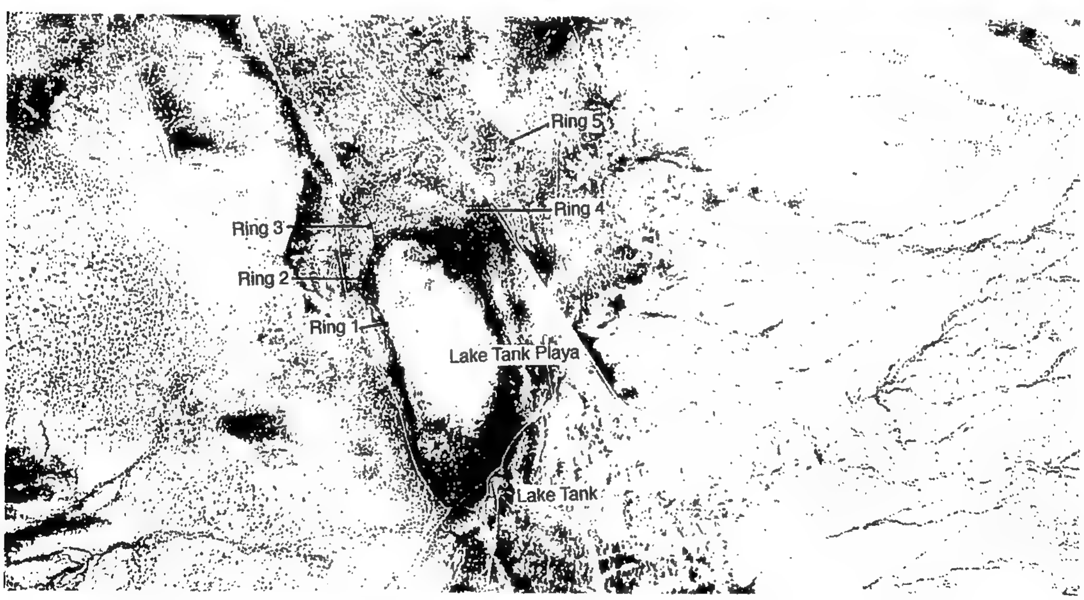


Figure 29. Multiple strandlines (bathtub rings) around Snail Playa (upper photo) and Lake Tank Playa (lower photo), southwestern McGregor Range (Desert and Desert SE quads). Strandlines can also be discerned in Trenched Playa and Little Playa in upper photo. In lower photo, the highest strandline at about 4,100 feet elevation (1,250 m) would have formed a lake that coalesced with a lake in Faultline Playa to the northwest, which would have created a lake some 6 miles long (10 km).

Wall of China (Poison Well) Playa, and many other playas on or near McGregor that were observed in this study indicates that Native Americans were visiting them and inhabited them at least temporarily. Evidence for human habitation at these playas is easily explained insofar as humans are in general attracted to lakes, including wet weather lakes and paleolakes, and McGregor has both.

Paleolakes

As has been shown, lakes do periodically form in McGregor Range playas. They would form more frequently and be larger if the rainfall conditions of 1880-1885, 1902-1906, 1911-1915, 1941-1942, or 1978-1991 were more frequent, or if summertime evapotranspiration rates were lowered, or both. Regional field evidence indicates that these conditions were clearly met during historic and prehistoric time. Table 3 lists all of the paleolakes that have been proposed for New Mexico and surrounding areas during the late Quaternary (after Hawley 1993). Two of the paleolakes in the table were near the McGregor area, Paleolake Sacramento on Otero Mesa into which the Sacramento River flowed, and Paleolake Otero in the Tularosa Basin into which most basinal drainage fed. To the table we can add a third paleolake that was largely on the McGregor Range, Paleolake Jarilla in the Jarilla Depression. All three paleolakes warrant discussion.

Paleolake Otero

A very large late Quaternary lake in the central and northern Tularosa Basin was originally proposed by Herrick (1904) at the turn of the century. He stated that

> . . . it may be regarded as certain that the great basin north of the Jarilla Mountains and extending northward to the east of the Oscuros was for a very long period covered by a salt lake in which gypsum, salt, and saline alkalis were deposited with intermittent regularity [Herrick 1904:179].

He called the megalake Lake Otero. Several versions of the reconstructed lake during its high phase have appeared in the literature (Figure 30, see Figures 6 and 28). Kottlowski (1958) stated that 5-25 ft of bedded gypsum was deposited in Lake Otero, which he viewed as more a series of salinas than a contiguous large lake, and attached a Pleistocene age to it (or them). The salinas presumably are present-day Lucero, No Name, White Ranch, and Parker playas, and possibly Davies and Old Coe playas (both the latter appear not to have salina-type playa floor deposits, however, for Old Coe presently is vertisolic, and Davies Playa sediments do not appear salina-like, based on observations in fall 1995. Kottlowski correlated the maximum extent of Lake Otero (or the Otero Salinas) with the last glacial-pluvial cycle, which he believed was time-contemporaneous with the maximum extent of Pleistocene Lake Estancia and other regional lakes. Whether the basin ever received enough runoff from the surrounding highlands during the last glacial-pluvial to cause all these salinas and depressions to coalesce—including Old Coe Lake—and form a High Lake Otero as proposed by Herrick is uncertain, but if it did its high water line was probably maximally no more than about 4,010 ft (discussed below). It presumably was less than 4,030 ft (1,228 m), the altitude of the divide with Hueco Basin to the south. Supposed ancient shorelines of Lake Otero observed by Herrick in the western part of the basin on the footslopes of the San Andres Mountains are considered to be fault-line scarps, because their bases at 4,100-4,300 ft altitude (1,250-1,311 m) are higher than any hypothesized lake could have been. Shoreline-like features in the eastern part of the basin (Culp-Grapevine canyons fanheads) are also fault-line scarps (Pipeline and Culp canyons quads) with bases at 4,300-4,400 ft altitude.

Table 3
Selected Data on Late Quaternary Lakes in the Southeastern Basin and Range Province, Arizona, New Mexico, Texas (USA), and Chihuahua (Mexico)
(adapted from Hawley 1993:Table 3)

Lake Name	Location Lat.	Location Long.	Lake Area km^2 (mi^2)*	Max. Lake Elev. m (ft)*	Basin Floor Elev. m (ft)*	Sill Elev. m (ft)*	Over-flow	Pre-Wisconsin Lake? Elev. m (ft)*	Remarks: • Lake Named by ♦ Major Sources of Information ▸ Playa Name(s) and elevations
Animas	32° 108°	15' 45'	388L (150)	1,279** (4,195)	1,259L (4,130)	1,292L (4,240)	No †	Yes	• Schwennesen (1918) ♦ Fleischhauer and Stone (1982) ▸ Alkali Flats - 1,259 m
Cloverdale	31° 108°	30' 45'	104ME (40)	1,576M** (4,170)	1,561M (5,120)	1,578M (5,176)	No †	Yes?	• Schwennesen (1918)
Cochise	32° 110°	15' 00'	310L (120)	1,274L** (4,180)	1,260L (4,135)	1,298L (4,260)	No	Yes 1,290L (4,230)	• Meinzer and Kelton (1913) ♦ Long (1966), Schreiber et al. (1989), Schreiber (1978), Waters (1989) ▸ Wilcox Playa - 1,260 m
Encino	34°	30'	47L (18)	1,882L** (6,175)	1,859M (6,100)	1,908LM (6,260)	No †	Yes	• Meinzer (1911) ♦ Kelley (1972), Kelly and Kelly (1972), Titus (1973) Bachhuber (1982, 1989)
Estancia	34° 106°	45' 00'	1,114L (430)	1,890L** (6,200)	1,856M (6,090)	1,933M (6,342)	No †	Yes 1,893L (6,210)	• Meinzer (1911) ♦ Bachhuber (1971, 1989, 1990), Lyons (1969), Titus (1973), Smith and Anderson (1982) ▸ Laguna del Perro - 1,841 m
Goodsight	32° 107°	30' 30'	39L (15)	1,372LM** (4,500)	1,358LM (4,456)	1,375LM (4,510)	No †	Yes	• Hawley (1965) ♦ Clemons (1979)
Hachita	31° 108°	30' 00'	150M (58)	1,262M** (4,140)	1,250ME (4,100)	1,262- 1,273M (4,140- 4,177)	? (to Palo-mas)†	Yes?	• Schwennesen (1918) ♦ Brand (1937), Hawley (1969), Morrison (1969), Axtell (1978), Miller (1981) ▸ Laguna de los Moscos - 1,250 m
King	32° 105°	00' 00'	900LM (350)	1,116LE (3,660)	1,103L 1,097M (3,620- 3,600)	— —	No †	Yes	• Miller (1981) ♦ King (1948), Boyd and Kreitler (1986), Hussain et al. (1988), Kreitler et al. (1990) ▸ Salt Flat - 1,097 m
Otero	32° 106°	45' 30'	466LM (180)	1,204ME (3,950)	1,184- 1,189M (3,885- 3,900)	1,220M (4,003)	No †	Yes	• Herrick (1904) ♦ Hawley (1983), Seager et al. (1987), Johnson et al. (1989) ▸ Lake Lucero - 1,184 m Alkali Flat - 1,189 m
Palomas	31° 107°	00' 00'	7,770L (3,000)	1,225LE (4,018)	1,150- 1,175M (3,773- 3,855)	1,225- 1,250M (4,018- 4,100)	No †	Yes	• Reeves (1969) ▸ Laguna Tildio - 1,150 m Laguna Guzman - 1,170 m Laguna Santa Maria - 1,150 m Salinas de Union - 1,175 m
Pinos Wells ‡	34° 105°	30' 30'	52ME (20)	1,859LE (6,100)	1,829LM (6,000)	1,902LM (6,240)	No †	Yes?	• Lyons (1969), Titus (1969) ♦ Meinzer (1911), Bachhuber (1971, 1982, 1986), Kelley (1972), Titus (1973)

Table 3 (cont'd)

Lake Name	Location Lat.	Long.	Lake Area km² (mi²)*	Max. Lake Elev. m (ft)*	Basin Floor Elev. m (ft)*	Sill Elev. m (ft)*	Over-flow	Pre-Wisconsin Lake? Elev. m (ft)*	Remarks: • Lake Named by ♦ Major Sources of Information ▸ Playa Name(s) and elevations
Playas	31° 108°	45' 30'	65M (25)	1,311LME (4,300)	1,303M (4,275)	1,314M (4,312)	? (to Hachita)†	Yes?	• Schwenneson (1918) ♦ Axtell (1978)
Sacramento	32° 10°	45' 30'	72M (28)	1,347M** (4,418)	1,308M (4,290)	1,347M (4,418)	(to King?) †	Yes	• Hawley (1993) ▸ John O. Flat - 1,308 m
San Agustin	34° 108°	00' 00'	780L (300)	2,115L** (6,940)	2,065L (6,775)	2,158M (7,078)	No †	Yes 2,135L (7,005)	• Powers (1939) ♦ Weber (1980), Stearns (1962), Markgraf et al. (1984), Phillips et al. (1992) ▸ San Agustin Playa - 2,065 m C-N Playa - 2,101 m
Trinity	33° 106°	30' 45'	199L (77)	1,431LE (4,695)	1,425L (4,675)	1,440M (4,725)	No †	Yes	• Neal et al. (1983)

Note that drainage-basin areas (ground- and surface-water) are still not well documented in many of these lake basins.
* L Data from cited literature. See remarks and Williams and Bedinger (1984)
M Estimates from maps and aerial photographs, 1:24,000 to 1:100,000 scales
E Estimates not well documented, need field verification
** Well-defined shoreline features mark high stands
† Ground-water outflow important discharge mechanism
‡ Late Wisconsin lake may not have formed

Pigott (1977:112) interpreted sediments "near Culp Canyon" (his Figure III-11, which resembles sediments exposed in Pipeline Barranca[3]) as "lacustrine and fluvial deposits" and correlated them with the Fort Hancock and Camp Rice formations (defined by Strain 1969 for the Hueco Basin and nearby areas). However, probably these are different facies of Culp Canyon alluvial fan sediments.

Shorelines of Lake Otero have not been unequivocally identified on the ground, but in the Landsat 4 photo, a contiguous shoreline is clearly evident whose southernmost perimeter is near Haystacks Tank just south of Parker Lake (see Figure 2). The shoreline coincides with the 3,950-foot contour line, which Hawley (1993) and Seaver et al. (1987) concluded was the maximum phase of Lake Otero (Hawley also suggested that Lake Otero was fed by both surface runoff and subsurface artesian flow). The visible shoreline in the Landsat image is either a high stand, as Hawley, Seager, and their colleagues concluded, or recessional from an earlier higher phase.

If it does define the highest phase of Lake Otero, then Davies and Old Coe paleolakes would have been separate and slightly higher-lying lakes if they filled to their sills (seven and 11 ft higher, respectively). A sill at 3,966 ft presently separates Old Coe depression from Davies depression, and a sill at 3,957 ft separates Davies depression (coalescent with East-West Dry Tank depressions) from the 3,950-foot level of Paleolake Otero. If both lakes filled to their sills during the last glacial-pluvial period (12,000-20,000 years ago) overflow would have been north, paternoster-like, involving 11- and seven-foot drops into Paleolake Otero. Both Old Coe and Davies paleolakes would then have held relatively fresh water, not alkaline water as did Lake Otero.

[3] Pipeline Canyon—as it is labeled on the USGS Pipeline Canyon quad and after which the quad is named—is a toponymic misnomer It is actually a *barranca* (vertical walls, flattish floor) cut into the Culp Canyon alluvial fan. It should be called Pipeline Barranca and is called such here.

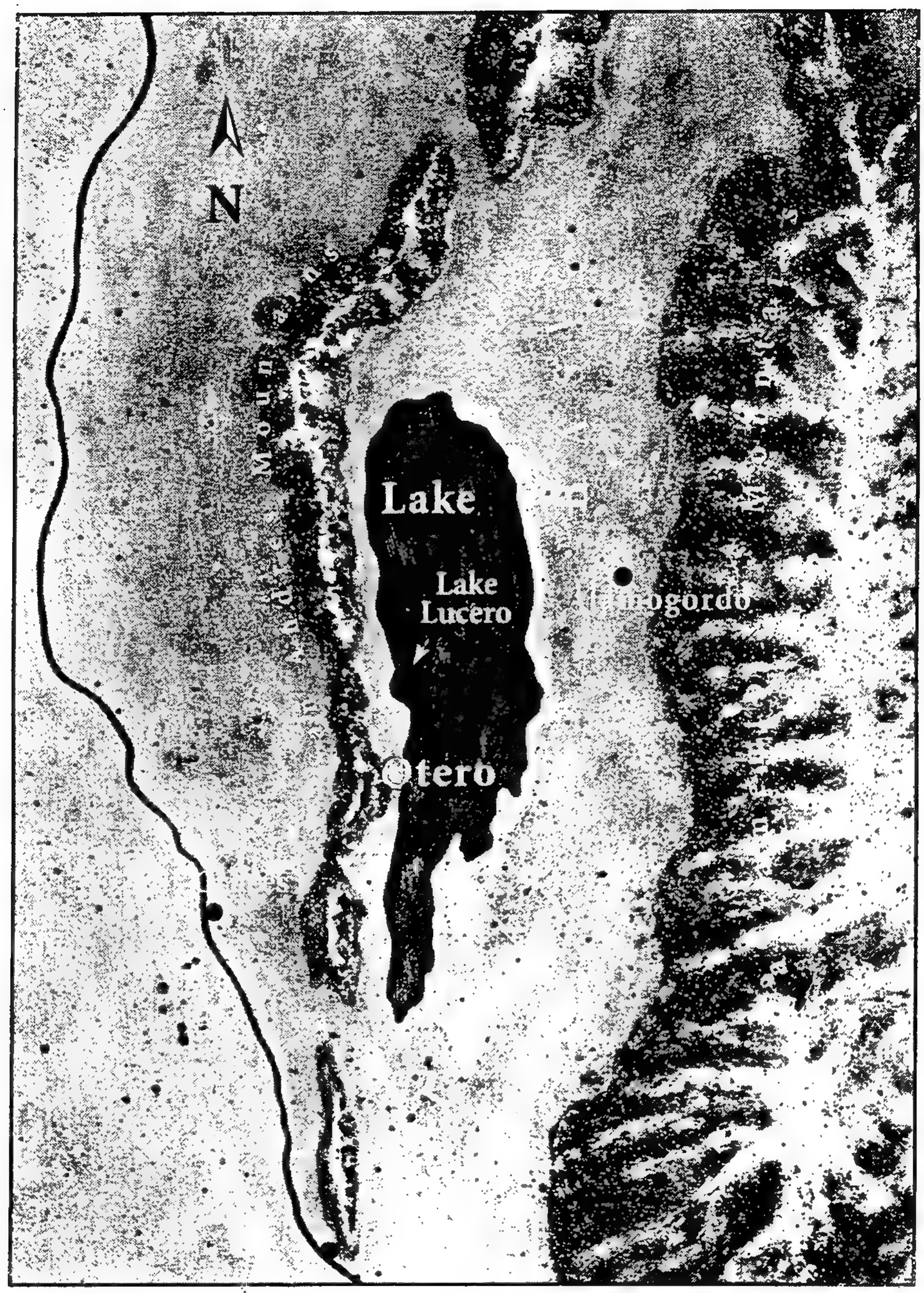


Figure 30. Paleolake Otero at maximum phase as reconstructed by Mangimeli and Eidenbach (1993) based on Herrick (1904). Following Herrick, Mangimeli and Eidenbach estimated the area of Lake Otero as approximately 1,600 square miles (4,144 km^2), but do not give an estimated surface elevation. Their version is much larger than Hawley's (1993) version, which covers 180 square miles (466 km^2) in area with a surface elevation of 3,950 ft (1,204 m).

Figure 28 shows the two versions of Paleolake Otero. Herrick's version, called here High Lake Otero, is similar to that defined by the dashed shoreline at the 4,010-foot contour interval, and Hawley's and Seager et al.'s (1987) version, termed here Low Lake Otero, is defined by the dotted shoreline at the 3,950-foot contour interval. The dotted lines around Paleolakes Davies and Old Coe are, respectively, at elevations of 3,057 and 3,066 ft.

Assuming a Low Lake Otero scenario, if Old Coe paleolake filled to its sill (3,966 ft) it would have been 63 ft deep and seven by 3.5 miles wide, and about 25 square miles in surface area (72 km^2). If Davies paleolake filled to its sill (3,957 ft) it would have been 44 ft deep and six by three miles wide, and about 15 square miles in area (39 km^2). Both lakes would have had a combined fresh-water surface area of about 40 square miles (> 100 km^2). While this scenario is speculative it would explain why salina-type deposits are absent in Old Coe and Davies playas (such deposits, however, could be present but buried by post-lake alluviation from the Organ Mountains). The fresh-water scenario assumes that Coe and Davies paleolakes were mainly fed by runoff water rather than ground water, which Hawley (1993) thought was an important contributor to Lake Otero (and which probably was mineralized, as is the ground water that presently feeds it). Almost all runoff from the southern Tularosa Basin, including the west draining portion of the McGregor Broken Escarpment Zone, excepting that which fed Lake Jarilla, would have fed Old Coe and Davies paleolakes.

Lake Otero doubtless formed repeatedly, and its perimeter and surface area must have varied widely over short time periods, as it does today when it contains water, a variability that is endemic to all shallow closed basin lakes. When Lake Lucero was visited by the writer in late June 1996, it was dry, but according to longtime area ranchers Mr. Bill McNew, III, and Mr. Rob Cox (personal communications 1997), Lakes Lucero, White Ranch, and Parker all periodically reform, sometimes significantly so. According to Mangimeli and Eidenbach (1993) after heavy rains Lake Lucero may have a surface area up to 10 square miles (26 km^2).

According to Hawley (1993), Lake Otero was primarily fed by local streams from the San Andres-Oscuro ranges on the west and the Sierra Blanca-Sacramento-Jarilla ranges on the east. Both Herrick (1904) and Hawley (1993) posit that the major stream that once fed the lake was dammed off by the Carrizozo basalt flow in mid-late Holocene time. In addition, Hawley (1993) proposed that there was a significant ground water contribution to Lake Otero, drawing on an area that extended possibly as far north as the Estancia Basin and Chupadera Mesa.

Based on work he executed in the Doña Ana Range of Fort Bliss, Pigott (1981) proposed a fundamentally different genetic model for sediments in the Tularosa Basin and its history. He would have a very large basinwide Lake Otero extend from the northern Tularosa Basin southward into the Hueco Bolson in late Pleistocene time, a water body in which was deposited Fort Hancock sediments. A stream later flowing north-south in the two basins then deposited Camp Rice sediments. This bold idea has yet to be positively tested beyond Pigott's Doña Ana Range work, or widely accepted, but it warrants careful thought.

Paleolake Sacramento

High shorelines have been confirmed by Hawley (1993) around the basin into which El Paso Draw and the Sacramento River flow at the eastern toe of the Sacramento River fan. As indicated earlier, the basin is the John O. (Stevens) Flat near the La Heeta Harvey (Stevens) ranch on Cleones Tank quad (see Figure 3). A baymouth gravel bar at an elevation of 4,395 to 4,418 ft (1,340-1,347 m) and a sill at the latter elevation marks the deepest phase of the lake, which when full overflowed into Van Winkle Lake to the southeast (Van Winkle Lake quad). At its highest stand Paleolake Sacramento lay just beyond the southeast corner of Sixteen Canyon quad about six miles (9.7 km) east of the eastern boundary of McGregor Range (see Figures 1, 6, and 25). In the Pleistocene it periodically formed a high stand that overtopped its sill at times when pluvial Lakes Palomas, Animas, San Agustin, Otero, Jarilla, and other regional paleolakes formed. When full, Lake Sacramento expands to 30 square miles (78 km^2) in area, is over 6.5 miles wide (13 km), and about 130 ft deep (40 m), as measured from the Cleones Tank quad. The present central playa is 4,291 ft elevation (1,308 m) and is 2.5 miles north of, and 10 ft lower than, the La Heeta Harvey (Stevens) ranch headquarters. As indicated earlier, several times during 1940-1950 the lake filled to a level that almost flooded the Stevens ranch headquarters (Pearl Lewis, personal communication 1997), which would have made it over four miles in diameter. This raises a conceptual question: Does a lake that periodically reforms

in this century retain the name given to its larger Pleistocene equivalent? It seems reasonable to say yes. If one's answer is no, then what do we call lakes that are historically one-tenth, one-quarter, three-quarters (etc.) as large as their Pleistocene equivalents?

Paleolake Jarilla

Lake Jarilla is a very shallow, episodically ephemeral, somewhat linear north-south water body that forms periodically in the Jarilla Bolson. It last formed any significant size in 1941 when it was a mile or so in diameter and lasted several years (Mr. Bill McNew, III, personal communication 1997). During the Pleistocene, however, when Paleolakes Sacramento and Otero were largest, Paleolake Jarilla also was episodically large, but because of its shallowness and limited catchment and recharge area, its perimeter, geometry, and size were far more dynamic, mercurial, fluctuating, and complex. It must have frequently expanded and contracted, and ultimately dessicated over short timeframes. At its fullest the water surface was an estimated 4,010±10 ft elevation, with a probable maximum depth of about 25±10 ft at Salt Cedar Playa, whose floor is presently at an elevation of 3,088 ft (see Figures 16 and 28). At its maximum Paleolake Jarilla extended from an area north of Wilde Well to the Great Wall of China and Lone Butte playas, a linear distance of about 12 miles (19 km), but it may have been larger and deeper prior to dunal invasions. (Most of the area west of the Grapevine-Culp fan toe was then 10-20 ft lower but has been raised by recent dune in-migrations.) The lake drained north, possibly in segmented fashion, into the slightly lower Great Wall of China Playa (floor at 3,978 ft elevation), joining playa waters shed there from the Sacramento Mountains, and thence into Lone Butte Playa (floor at 3,969 ft elevation), and thence into the Gypsite Flats beyond, ultimately into Lake Otero.

The western limits of Paleolake Jarilla water were constrained by a slight topographic high north of the Jarillas to Escon Hill (west of Olden ranch-Moody corrals near the BLM sand pit) and thence to Tres Hermanos Buttes and beyond, though historic dune piles in and south of the Tres Hermanos have significantly blurred the picture. The topographic high would have confined the southern sector of Lake Jarilla, but north of Escon Hill the topography is less, which probably allowed high lake stage waters to spread out widely, pan-like. If Paleolake Otero reached a maximum elevation of 3,950 ft (1,204 m), as Hawley (1993) and Seager et al. (1987) concluded, and as visible shorelines at that elevation on Landsat 4 photos suggest, it would have been some 20 ft lower than the lowest outflow levels of the northern sector of Paleolake Jarilla.

Because it was so shallow it must have fluctuated widely in size, in duration, and in water quality, ranging from less alkaline during high stands to more alkaline during low levels, and less alkaline in the south to more alkaline in the northern sector as it dessicated into segments. It may have functioned as multiple ephemeral paternoster salinas during its dessicating phases. Here it should be noted that its playa sediments in the Cox Well-Salt Cedar playas areas, where not buried by recent alluvium and dunes, is alkali-like. A major factor in the study of Lake Jarilla is that recent sediment, both eolian and fluvial, is and has long been actively burying the lakebed and playa sediments.

In an apparent attempt to explain occupation of Pendejo Cave by humans, MacNeish hypothesized a pluvial lake east of the Jarillas in the Benton Well area. If a lake were near the cave in the late Pleistocene, its water and aquatic food resources and other amenities of a lakeside environment would be a *raison d'etre* for the long presumed human habitation there. Khresat (1993) tested this lakeside model in the Benton Well area and concluded that no lake had existed. However, a lake does periodically exist, but when it forms its southern shore at its highest stage was several miles farther north (see Figure 28). As of this writing, traces of Lake Jarilla shorelines, either highest or recessional phases, have not been identified on the ground or on air photos. Probably this is because of the dynamic nature of Jarilla Bolson sedimentation (historic and prehistoric episodic fan accretions, eolian burials, etc.) and because of the presumed shallowness of the lake, so that even at highest stage, the likelihood of shorelines being preserved and observed is low to nil.

High Paleolake Otero Scenario

It is possible that Hawley's estimate of Lake Otero's elevation at 3,950 ft, represented by the shoreline evident on Landsat 4 photos (see Figure 2), is a lower recessional phase and that Paleolake Otero was in fact higher as Herrick (1904) originally proposed, perhaps by some 60 ft, to about the 4,010-foot contour line. If so, Paleolakes Otero, Jarilla, Old Coe, and Davies would have been joined as one, supporting Herrick's hypothesis. An eastern finger of the High Paleolake Otero would have been shallow and pan-like, extending southeast into the Jarilla Bolson (see Figure 28). The flattish playa-like, alkali-rich surface of a large part of the Tularosa Basin at this approximate level, especially the expansive area north, west, south, and east of the Tres Hermanos Buttes, suggests that Herrick's model may not be so far-fetched and may be correct. It is appropriate here to allow Herrick (1904:185) a final word, and reflect on it:

> So far as we can now determine, the area of this ancient lake may have been from 1600 to 1800 square miles. We have made no examination to the south to ascertain if the nature of the barrier can be made out. It may have extended nearly to the Jarilla Mountains. From the nature of the case, the old shore lines must be deeply buried under the talus from the mountains whose fans spread out a great mantle of lime debris.

GEOMORPHOLOGY AND SOILS

Topography

The surface expression of the McGregor Range varies from flattish in the Tularosa Basin and parts of Otero Mesa to very steep in the Hueco and Sacramento mountains. Figure 31 shows general relief of McGregor Range, and Figure 32 is a raster map of Fort Bliss in general that shows six levels of relief. The map roughly approximates the five geoecological natural zones of McGregor recognized in this study (see Figure 4).

The Five Geoecological Natural Zones of McGregor

As indicated in the Introduction, the five natural zones are the Jarilla Bolson Zone, Tularosa Basin Zone, Broken Escarpment-Hueco Mountains Zone, Otero Mesa Zone, and the Sacramento Mountains Zone (see Figure 4). Each has a mix of genetically related landforms and environmental processes and conditions that sets them apart and gives each a distinct geoecological identity. An evaluation of McGregor geomorphology and soils is best done in the context of these five zones.

Jarilla Bolson Zone

This zone encompasses the northwestern part of McGregor, including the normal-faulted fans fronting the Sacramento Mountain escarpment, the Negro Ed-Culp-Grapevine canyon fans complex, the Jarilla Mountain footslopes-Jarilla Bolson-Jarilla Gap areas. It is a zone that was once dominated by Paleolake Jarilla, which even now occasionally reforms in a smaller scale during wet periods. This zone also has several associated perennial springs (Water Canyon in the Jarillas, Culp Springs near County Road 506, Negro Ed Springs at the mouth of Negro Ed Canyon, and other springs in the Sacramentos). Eleven sediment-soil sites were studied in detail in this zone, and they are best evaluated within the site context.

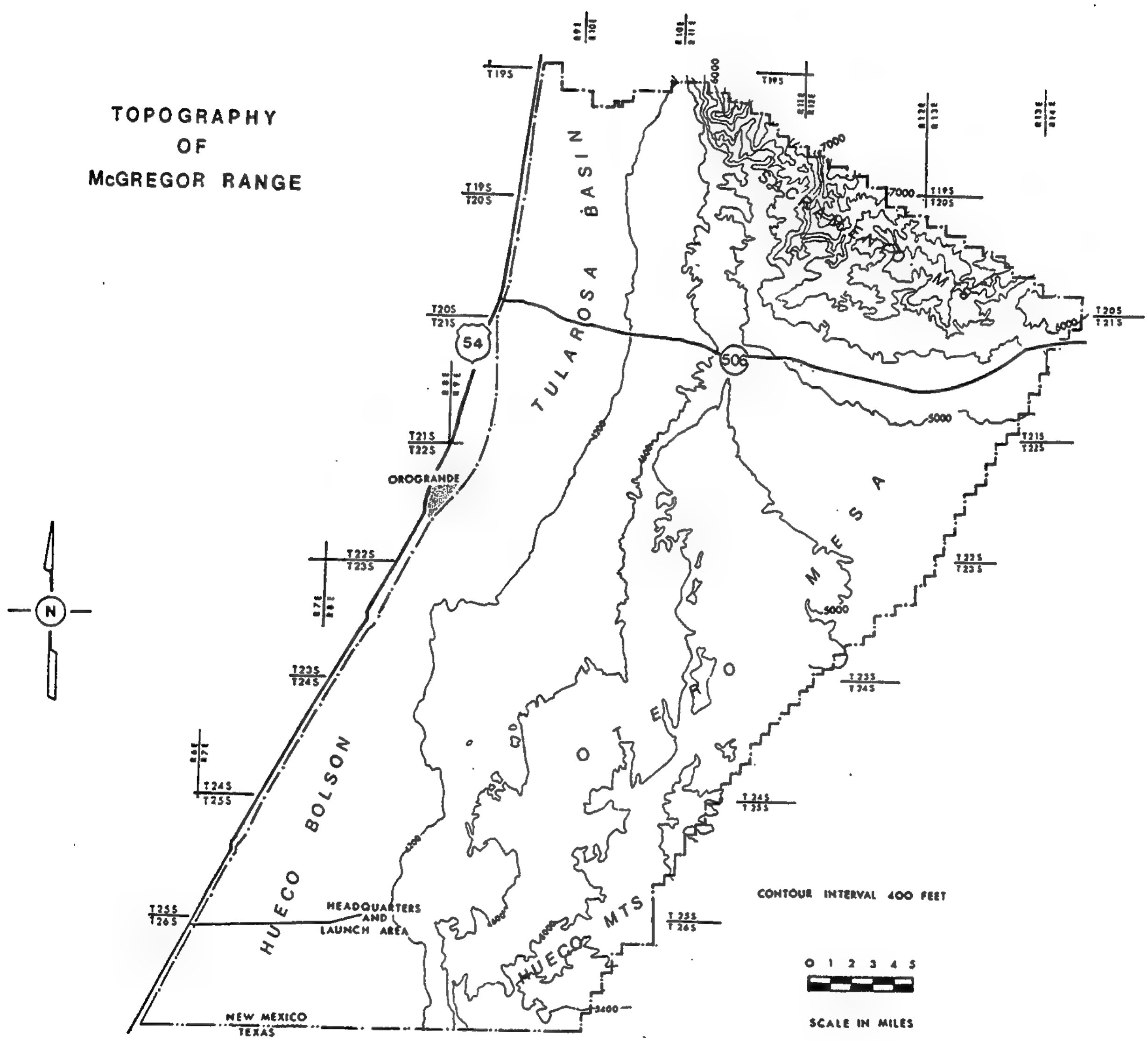


Figure 31. General topographic map of the McGregor Range (after Pigott 1977:Figure III-8).

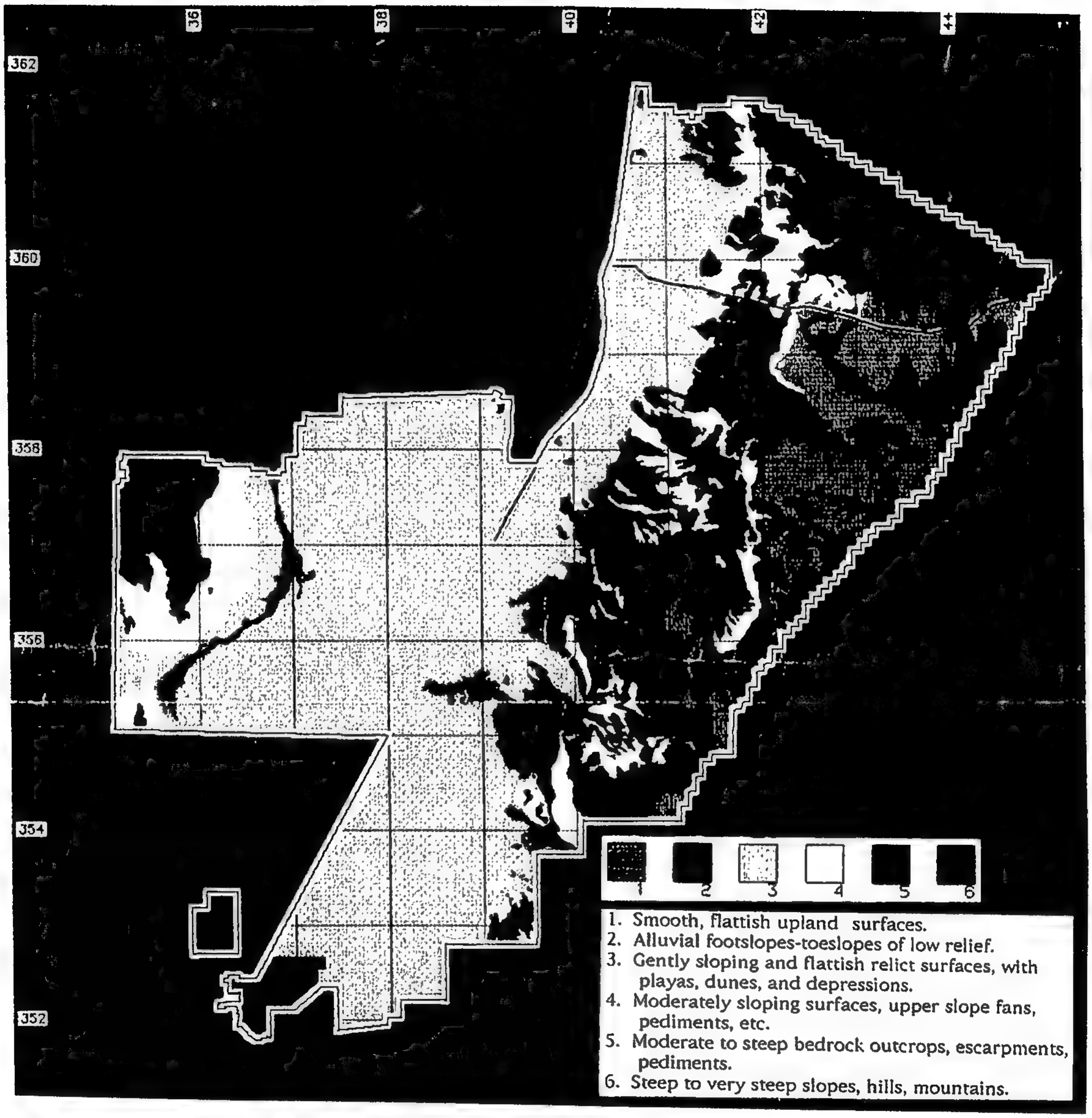


Figure 32. Raster map of general relief and sloped lands of Fort Bliss and McGregor Range, southcentral New Mexico-West Texas. The six categories are based on topography. (Produced by USACERL, Champaign, IL, see text.)

Grapevine-Culp Canyon Fans, Mid- and Upper Slopes

This area is of interest for several reasons. One is that multiple basin-bordering normal faults cut the Bug Scuffle, Grapevine, and Culp canyons fanheads (see Figures 16 and 18). Not only do they play a fundamental regional role in producing the Sacramento Mountains and the Tularosa Basin, they have a local role in producing relict paleofans along the fanheads of each of these three canyons (see Figures 16 and 18). While these faults and their role in creating regional and local landforms are of key geomorphic importance to the area, discussion of them is reserved for the Broken Escarpment-Hueco Mountains Zone section below.

This area is also geomorphically important in that some peculiar process interactions occur between dune trains that advance onto the Grapevine-Culp alluvial fans from the basin and their episodic burial by alluvium during stormflow periods. Dune trains that are undergoing burial are observed in other places in the Jarilla Bolson (see Figure 17), but are most notable on the Grapevine-Culp fans (see Figure 18). Another peculiarity is that dunes that escape burial climb over the escarpment into the mountains. But this sand is ultimately washed back onto the fans, and even into the basin, as sandy alluvium. The process is manifested in the stratigraphy at site 3 near Ditch Camp on Sand Creek North (see Figures 16 and 18). Five units are exposed here in the south wall of this probably historically cut barranca (Figure 33). Unit 1 consists of at least two mudflow deposits which bury Unit 2, an eolian sand sheet (note artifacts in upper part of sand sheet). Subjacent Units 3, 4, and 5 are made up of alluvially recycled sands that were once blown up into the foothills.

Apparently this part of the Tularosa Basin experiences an eolian Venturi effect whereby prevailing southwest winds are channeled east-northeast over the southern Sacramento Mountains above the Grapevine-Culp fanheads (see Figures 16 and 18). This effect is particularly noticeable on the divide between Sand Canyon North and Culp Canyon, where large sand piles have accumulated during the Holocene, and which probably were accumulating during the late Pleistocene as well (see Sand and Culp Canyon dune piles on Figure 18). The pedostratigraphy at site 3 indicates that dune accumulation and fluvial wash-back have occurred repeatedly in prehistoric time, probably many times during the uplift of the Sacramento Mountains and commensurate down-dropping of the Tularosa Basin. Such buried sand and mudflow sequences probably function as local aquifers and aquicludes in the subsurface of the piedmont fans along the eastern basin and could have produced perched water tables and springs.

That Sand Creek North was historically cut is suggested by road gravel remnants that are north-south aligned on the pre-barranca surface on either side of the creek. The new (post-cut) road meanders down and across the creek. Post-settlement barranca cutting is also suggested by mudflow deposits which derived from Grapevine Canyon, but which occur on both sides of the barranca (Figure 34; see Figure 33). The mudflows, both of which contain prehistoric artifacts, had to have occurred before the barranca existed (see also Figure 18).

As a matter of historic interest, it was these nutrient-rich mudflow deposits that Oliver Lee cultivated here at the turn of the century on his Thousand Acre Farm (Ditch Camp). To water the tract, in 1894 he and others began the now-famous hand-dug ditch from Circle Cross Ranch on the Sacramento River across the mountains to Ditch Camp, also called Old Ditch Camp, which later was extended to Sacramento City (Messers Pete Atkins and Roy Holcomb, personal communications 1997; Faunce 1996; Freeman 1977). It is worthy of note that this area on Grapevine Canyon fan, cultivated between 1904 and 1918, is now badly eroded by surface sheet wash and eolian deflation (Figures 35-39) and is the source of episodic dust plumes that can be seen from Highway 54 (cf., Figure 9). It is also worthy of note that the Ditch Camp area has enormous quantities of fire cracked rock, surface sites, and various other prehistoric cultural remains, and that Artifact Tank[4] constructed in the midst of it has ramparts made largely from these prehistoric cultural materials (see Figure 36).

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[4] This tank may have been the one called Gravel Tank by Baca in Freeman (1977:124).

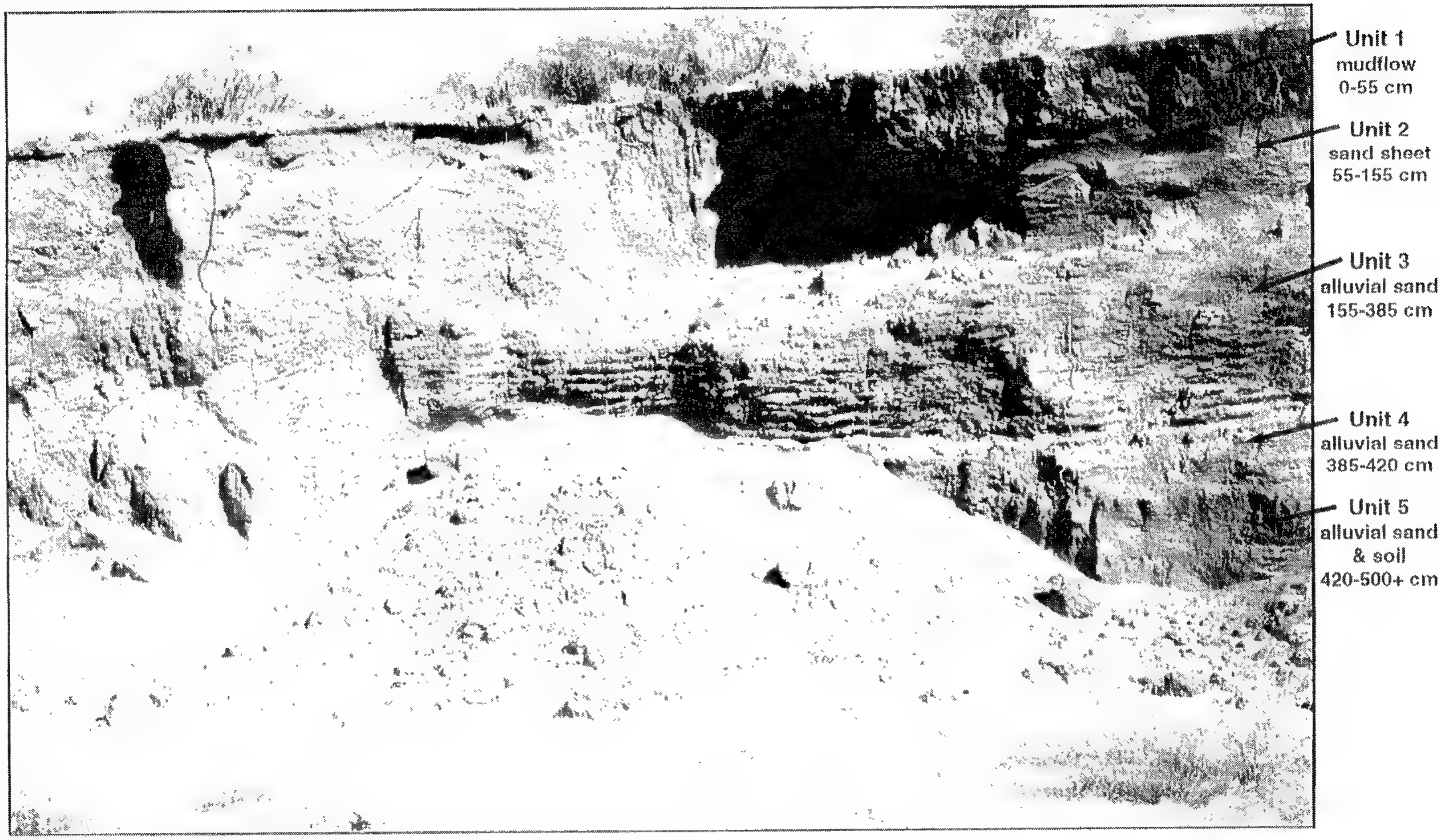


Figure 33. Sand Canyon North, site 3, Grapevine Canyon fan, soil units. Five units are exposed in this south wall of probably historically cut Sand Creek Barranca. Units 1 and 2 are, respectively, mudflow deposits over an eolian sand sheet (note artifacts in upper part of sand sheet). The other units are alluvially recycled, originally eolian sands. An eolian venturi effect channels sand up onto the escarpment here, where a large sand pile has accumulated during the Holocene, and probably during the late Pleistocene as well. Storm waters episodically wash the sand back as alluvium onto the Grapevine Canyon fan. The pedo-stratigraphy here indicates that the process has happened repeatedly.

Figure 34 Views of Sand Canyon North. Upper photo is looking north, showing south-facing Sand Canyon North cut wall at Ditch Camp on the mid-upper part of Grapevine Canyon fan. Upper dark layer consists of two artifact-bearing late prehistoric mudflows (see Figure 33, Unit 1) that buried an artifact-bearing (in upper part) reddish sand sheet (see Figure 33, Unit 2) that lies above several backwash sandy alluvial units (see Figure 33, Units 3-4). Lower photo shows how the mudflow unit sloughs off and drapes across the lower units just downstream from the upper photo.

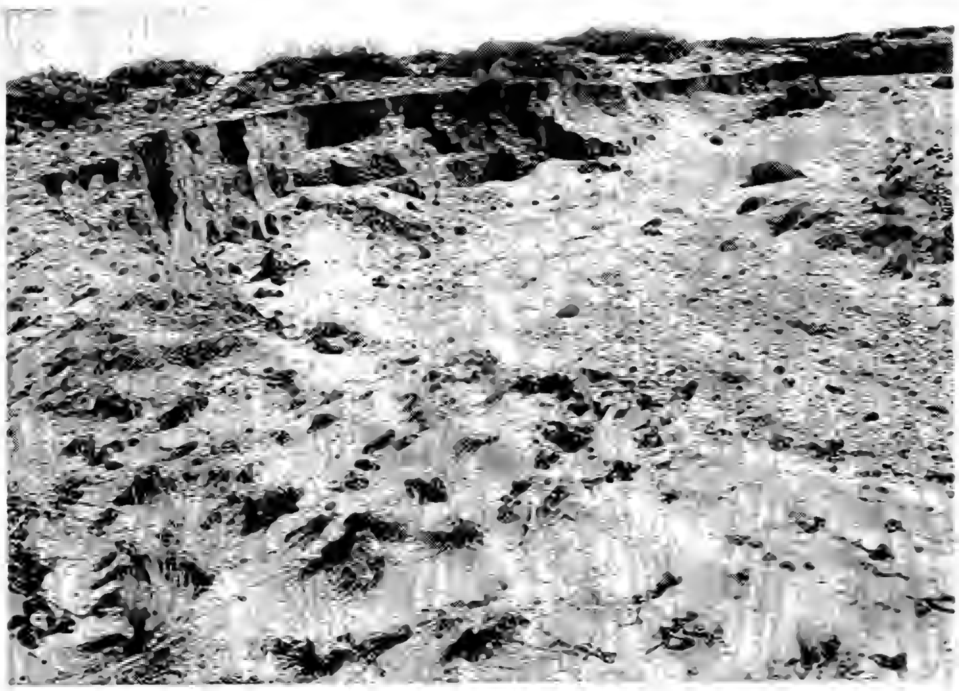


Figure 35. Scenes along Sand Creek North, at Ditch Camp on upper mid-slopes of Grapevine Canyon fan. Upper photo looks west down Sand Creek North to the described section of site 3 in Figure 33. Note that mudflow is thinner and discontinuous on the south side of the barranca, but not on the north side (see Figure 34), indicating that the flow was out of Grapevine Canyon to the north. Note also that the surface has a mesquite-anchored historic dune sheet. Lower photo is a south view of the north-facing wall of the barranca taken from its floor, upslope from site 3, showing mesquite-anchored sands atop a discontinuous mudflow (see Figure 33, Unit 1) over a buried sand sheet that contains artifacts (see Figure 33, Unit 2), over a stratified sandy 'backwash' alluvial unit that has precipitated caliche in it (see Figure 33, Unit 3).

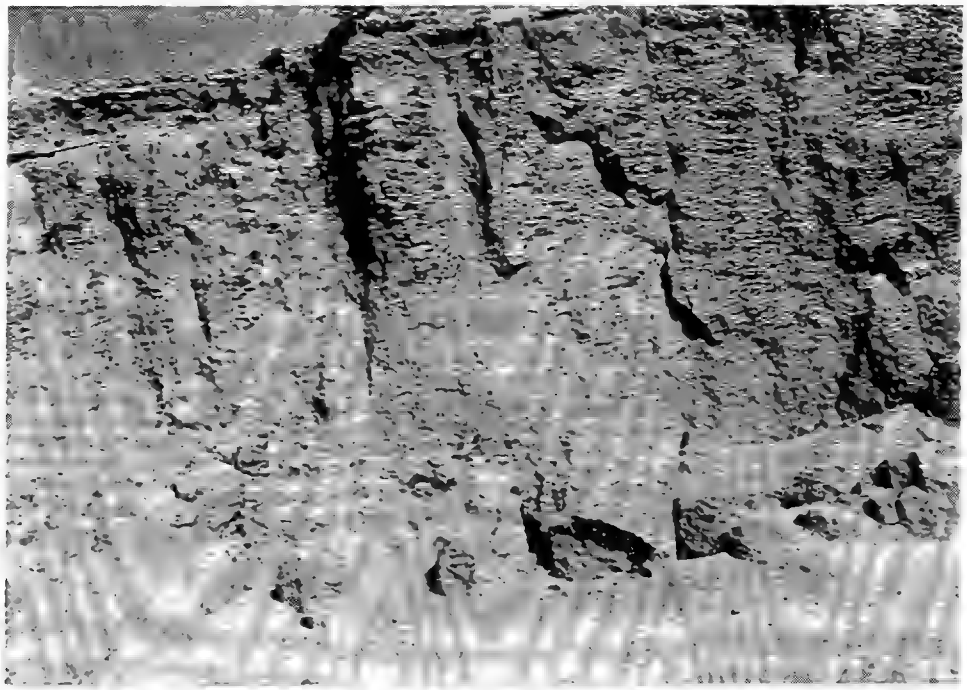


Figure 36. South wall of Sand Creek North, at Ditch Camp on upper mid-slopes of Grapevine Canyon fan near site 3. Upper photo shows a thin stratified mudflow (upper left of photo) over a buried sand sheet with artifacts (upper middle of photo) above fluvially redeposited sand. Lower photo shows artifacts at the base of a calcified sand sheet below a recent coppice mound, near site 3.

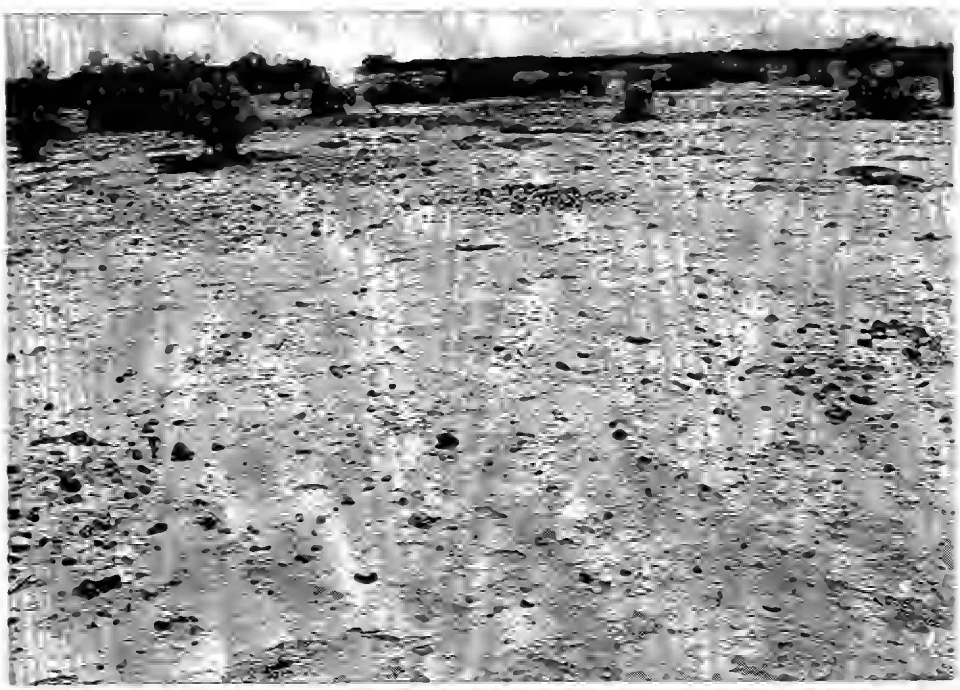


Figure 37. Photos taken at Ditch Camp. Upper photo shows a young shrub on a remnant erosional pedestal from around which the soil has been removed, which demonstrates the efficacy with which wind and water erode these alluvial units after they are deposited. Lower photo is view looking west at fire-cracked rock and prehistoric sites now exposed at the surface owing to eolian and sheetwash scour, both processes that function as the "surface exposing vector" for these artifacts, as opposed to surface mounding via bioturbation (pocket gopher mounds in background) that functions as the "artifact burying vector."

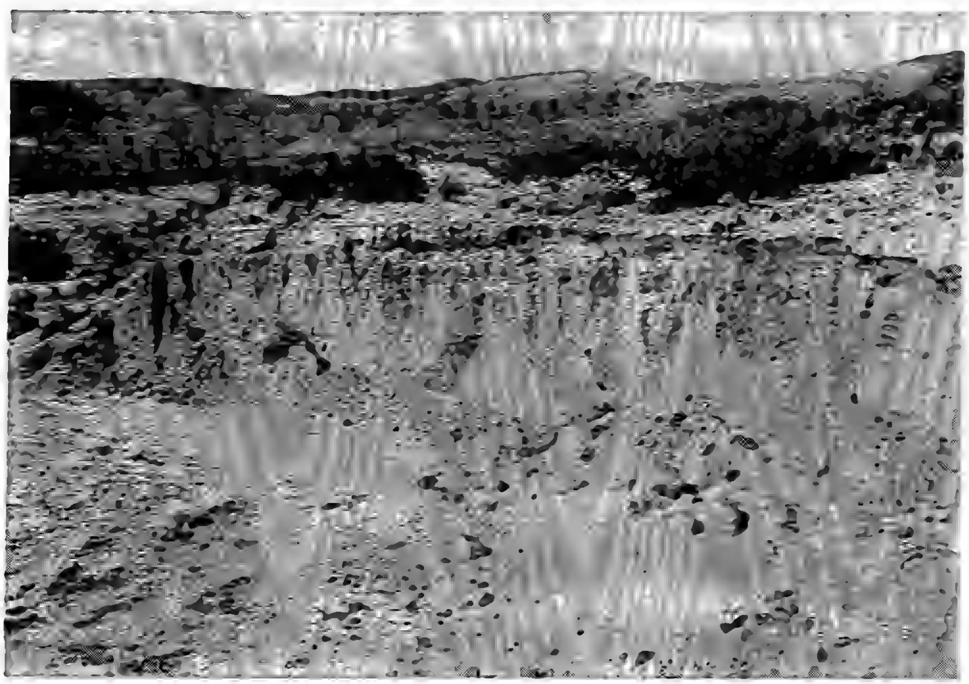


Figure 38. Two modes of fluvial erosion on McGregor Range. Upper photo, looking north from the Cactus area (site 15) of Wilde Tank quad, shows a process known as 'sod stripping' in progress, which is a minimalist form of backwasting. New sand is forming on newly exposed ground to the left of crouched field assistant D. N. Johnson. Lower photo shows headcut erosion and historic creation of Sand Creek North at Ditch Camp (cf., Figure 16).

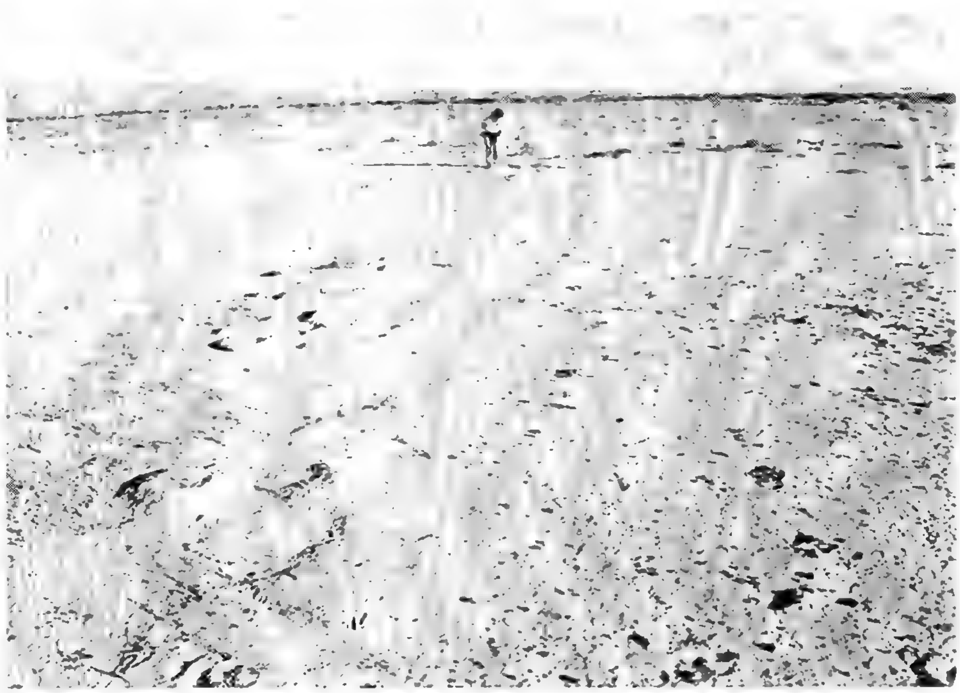


Figure 39. Secondary site formation processes—sheetwash and eolian scour (eroding vector) versus surface mounding via gopher bioturbation (burying vector)—impact the archeological record: (a) looking north to the Sacramento Mountains from an area near Fish Tank, downslope from the main part of Negro Ed Canyon in the far northwestern part of McGregor Range, shows the amount of surface erosion that has occurred via slopewash and eolian scour in the short time that the two creosotebushes germinated, grew, and died. The roots give an estimate of the amount of sediment removed, up to 35 cm in the case of the nearest shrub (figure is field assistant D. N. Johnson); (b) Escondida site 4, on lower midslopes of Grapevine Canyon fan about 4 miles (6 km) downslope and west-northwest of Ditch Camp, shows older, almost totally downwasted gopher mounds. Fire-cracked rock and other cultural resources are as abundant here on Grapevine Canyon fan as they are at Ditch Camp 6 km upslope.

Multiple mapping units are present on these fan complexes, but because of migrating sand sheets and dune piles alternating with fluvial-mudflow episodes they would not be constant with time.

Grapevine-Culp Canyon Fans, Lower Slopes

The Escondida site was described by Hedrick (1967:19) as one "situated in a dry lake bed surrounded by sand dunes" which consists of "a village site containing trash middens, surface materials, rock hearths and room remains." While it may have been a temporary playa at one point, as could any portion of the fan if the natural downslope drainage is blocked by dunes, the Escondida area does not now function as a playa insofar as it is open downslope and to the west (see Figure 39b). It does occupy a footslope position on the Grapevine Canyon fan so that it receives episodic runoff from upslope. It is within the A1 mapping unit on the Deadman quad.

Because the site is visually impressive, and is reported to be a village site with at least one structure, the possibility was advanced that the fan surface was utilized for prehistoric agricultural purposes. If it was, probably corn would have been a likely crop. Consequently, to shed light on the matter, and to gain an insight on the nature of the Escondida sediments, three two-inch diameter sediment cores were pulled from the center of the dirt roadway that runs across the site (abundant fresh tire tracks indicated recent use by others). Care was taken to ensure that the Giddings rig and towing vehicle stayed on the track and thus was minimally intrusive to site integrity. Two of the cores were for pollen analysis, the third for sediment-soil description, particle size, and chemical analyses.

The sediment-soil description is in Appendix D, and the laboratory chemical and physical data are in Table 4. Particle size data were graphed (Figure 40), and the data indicate that the soils are nutrient rich, and, if utilized for agriculture, would probably have produced good yields, like similar soils apparently did for Oliver Lee's Thousand Acre Farm at Ditch Camp where wheat and corn were grown during 1904-1918 (Freeman 1977). Moisture utilized would have been any remnant moisture from the last rainfall or fluvial event, or both, plus any watering artificially applied by Native Americans. Pollen analysis, conducted by Dr. Stephen A. Hall (personal communication 1996), palynologist, Geography Department, the University of Texas at Austin, yielded the following results:

> Escondido Playa. The base of this core has some pollen, poorly preserved, with lots of charred particles. The pollen has been partly altered by weathering. Again, there is enough charred particles for an AMS date. The pollen may or may not be suitable for scientific study—hard to say until I count this material.

Moody Lowlands: BLM Site 6, Holcomb Playa, Great Wall of China Playa, Railroad Gypsite Site, and Cedar Lakes

The area north of the Jarillas and south of Lone Butte is referred to as the Moody Lowlands, or Moody Wind Gap in this report. It is named for Moody Tank, which lies near the middle of the area (also, the corrals at Olden Ranch 3 km east of the BLM Sand Borrow Pit and near the base of Escon Hill are called Moody Corrals by area ranchers). That the area is a wind gap is demonstrated by the vast quantities of sand that have historically and prehistorically accumulated in the area. When the sand that migrates northeastward out of the western and southwestern parts of the Tularosa Basin encounters the Jarilla Mountains, it either passes south through the Jarilla Wind Gap, over the Jarillas through Sand Gap, or north of the range through the Moody Lowlands. The areas investigated in this section involve the latter and include: (1) the BLM Pit; (2) Holcomb Playa and adjacent Great Wall of China Playa; and (3) the Railroad Gypsite site in the gypsite flats area of northwestern McGregor and Cedar Lakes just west of the Railroad Gypsite site (and Highway 54).

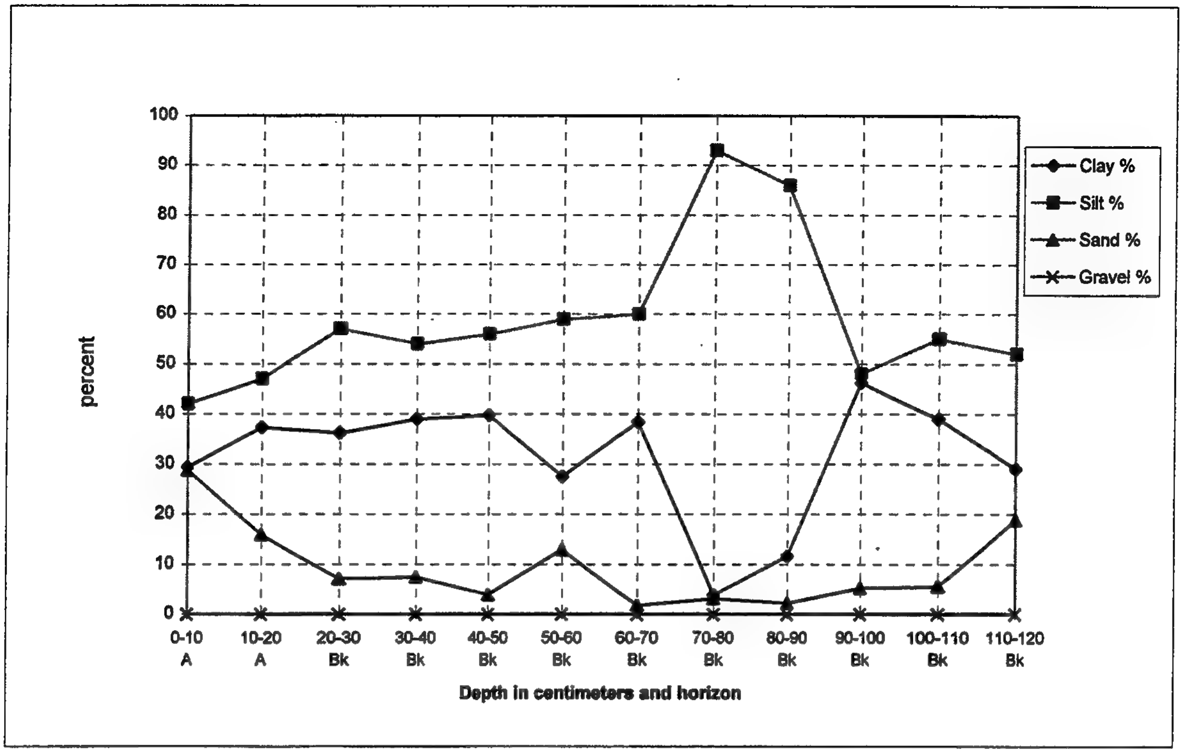
Table 4
Escondida, Site 4, McGregor Range, New Mexico
Particle Size and Chemical Data

Particle Size Data

Horizon	Depth	Sediment / Percent: Clay	Silt	Sand	Fine Silt	Coarse Silt	Very Fine Sand	Fine Sand	Medium Sand	Coarse Sand	Very Coarse Sand	Gravel	Textural Class
A	0-10	29.40	42.00	28.90	24.20	17.50	9.80	18.20	0.70	0.10	0.20	0.00	CL
A	10-20	37.40	47.00	16.00	34.40	12.20	6.50	9.00	0.30	0.10	0.10	0.00	SICL
Bk	20-30	36.30	57.00	7.20	37.30	19.20	4.60	2.30	0.10	0.10	0.10	0.00	SICL
Bk	30-40	39.00	54.00	7.50	35.90	17.70	5.30	2.00	0.10	0.10	0.10	0.00	SICL
Bk	40-50	39.80	56.00	4.00	39.60	16.50	2.60	1.30	0.10	0.10	0.00	0.00	SICL
Bk	50-60	27.60	59.00	13.00	29.80	29.50	11.60	1.20	0.10	0.10	0.10	0.00	SICL
Bk	60-70	38.40	60.00	1.80	45.60	14.20	1.00	0.70	0.00	0.10	0.00	0.00	SICL
Bk	70-80	3.90	93.00	3.20	76.20	16.70	1.00	1.20	0.50	0.50	0.10	0.00	SI
Bk	80-90	11.70	86.00	2.30	80.30	5.70	1.10	0.90	0.10	0.10	0.10	0.00	SI
Bk	90-100	46.30	48.00	5.30	37.60	10.80	3.40	1.70	0.10	0.10	0.10	0.00	SIC
Bk	100-110	39.00	55.00	5.60	38.20	17.30	3.80	1.60	0.10	0.10	0.00	0.00	SICL
Bk	110-120	29.10	52.00	18.90	21.20	30.80	16.90	1.80	0.10	0.00	0.10	0.00	SICL

Chemical Data

Horizon	Depth	Ca meq/100g	Mg meq/100g	Na meq/100g	K meg/100g	Sum of Bases meq/100g	Acidity meq/100g	Al meq/100g	CEC by sum of cations meq/100g	CEC-7 (NH4OAc) meq/100g	CEC Bases + Al	Al Sat %	Base Sat by sum %	Base Sat by CEC-7 %	Organic Carbon %	Salt pH .01M CaCl2	Water pH
A	0-10 cm	42.90	3.10	0.10	0.70	46.80	0.00	--	46.80	13.70	--	--	100.00	100.00	0.50	7.50	8.10
A	10-20 cm	46.20	4.30	0.40	0.50	51.40	0.00	--	51.40	16.30	--	--	100.00	100.00	0.60	7.60	8.20
Bk	20-30 cm	47.90	5.10	1.10	0.30	54.40	0.00	--	54.40	16.00	--	--	100.00	100.00	0.40	7.60	8.10
Bk	30-40 cm	46.80	6.30	2.40	0.30	55.80	0.00	--	55.80	16.90	--	--	100.00	100.00	0.40	7.60	7.80
Bk	40-50	48.10	7.50	3.30	0.30	59.20	0.00	--	59.20	16.80	--	--	100.00	100.00	0.40	7.50	7.70
Bk	50-60	45.40	6.70	2.80	0.20	55.10	0.00	--	55.10	12.90	--	--	100.00	100.00	0.20	7.50	7.70
Bk	60-70	42.50	8.70	3.80	0.20	55.20	0.00	--	55.20	16.20	--	--	100.00	100.00	0.40	7.50	7.60
Bk	70-80	92.30	9.10	3.50	0.20	105.00	0.00	--	105.00	15.70	--	--	100.00	100.00	0.40	7.40	7.50
Bk	80-90	82.30	10.30	4.00	0.30	96.90	0.00	--	96.90	18.90	--	--	100.00	100.00	0.40	7.40	7.50
Bk	90-100	63.20	9.80	3.60	0.30	76.90	0.00	--	76.90	18.00	--	--	100.00	100.00	0.40	7.40	7.50
Bk	100-110	61.40	9.50	3.20	0.30	74.40	0.00	--	74.40	16.90	--	--	100.00	100.00	0.30	7.50	7.50
Bk	110-120	54.00	7.90	2.80	0.30	65.00	0.00	--	65.00	13.40	--	--	100.00	100.00	0.30	7.40	7.60



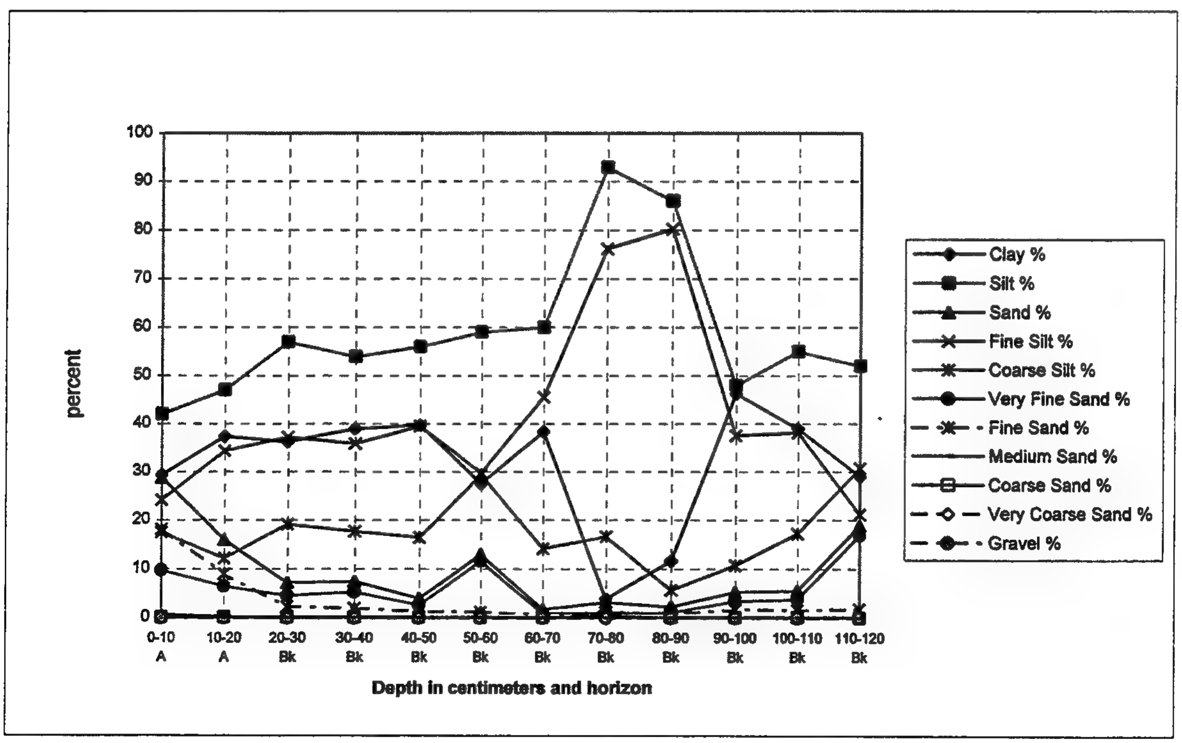


Figure 40. Escondida, site 4, on footslopes of Grapevine Canyon fan, northwestern McGregor Range, depth functions of four (upper) and 11 (lower) particle sizes.

1. *BLM Pit.* The BLM Sand Borrow Pit is useful to this study because it lies immediately next to McGregor, it has excellent exposures, and is accessible. It would probably fall within the DSC/A1/Pl mapping unit (because it is buried, the Berino-like soil that is present would not show up in the mapping unit designator). The described section was the thickest and deepest of all the cuts in the borrow pit, and consisted of three units that are present throughout the borrow pit. Figures 41 and 42 show the field relations and the three units. The basic stratigraphy of the pit is: coppice mounds on the surface (Unit 1), which overlie a weak buried soil developed in a sand sheet (Unit 2), which overlies a well-developed paleosol with a petrocalcic horizon (Unit 3) which has formed in an apparent ancient dune (while no dunal stratigraphy is preserved, lack of pebbles and location of the unit in the Moody Lowland windgap strongly suggests that it was a dune, probably a sand pile or thick sand sheet).

The sediment-soil description for the BLM site 6 is in Appendix D, and the laboratory chemical and physical data are presented in Table 5. Particle size data were graphed (Figure 43) A and the profile schematic was generated from these data (Figure 44). Figure 45 shows calcified cicada burrow structures that are common in the top of the 3B4kmb (petrocalcic) horizon. Uncalichified cicada structures are present in the overlying horizons, and though there are few in the 2Akb horizon of Unit 2, they are common in the 2Bkb horizon. Burrow structures range from few in number to being common in the 3B1tkb horizon of Unit 3, but they completely dominate the lower horizons of Unit 3, including the upper part of the petrocalcic horizon.

A slight amount of $CaCO_3$ has been leached from the coppice dune and precipitated as filaments in the 2Akb horizon of Unit 2. Likewise, some $CaCO_3$ from the Unit 2 soil, and possibly from the coppice dune above it, has leached down to Unit 3 and precipitated as thin filaments of caliche in the 3B2kb horizon.

Three ^{14}C dates were obtained from each of the three units but in an exposure adjacent to the one described (see Figures 41 and 42; see also Table 1). One date was on Russian thistle (*Salsola kali*), or tumbleweed, collected from a thin (2 cm-thick) layer at the base of a largely stratified coppice dune. The date indicates that this coppice dune formed about 40 years ago, probably during the mid to late 1950s or early 1960s, when it buried the tumbleweeds. The *Salsola* plants were growing on the dune sheet soil of Unit 2, which was surface exposed until the late 1950s or early 1960s.

A second date on soil organic carbon (SOM) extracted from the first buried soil of Unit 2 gave a mean residency time age of 670±90 ryB.P. (see Table 1). The date indicates that Unit 2 is prehistoric and was deposited sometime in the Holocene, probably late Holocene. A third date, determined from inorganic carbon ($CaCO_3$) taken from the upper 10 cm of the petrocalcic layer in the 3B4kmb horizon, gave an age of 11,710±110 ryB.P. The date suggests that this soil has been around during most or all of the Holocene, which makes the dune in which it has formed at least as old. These dune units, and the washback sand units exposed in Sand Canyon North (described above), provide strong collective evidence that the area has long been a dune accumulation area, and that therefore landscape destabilizing agents other than humans and stock animals have been at work.

2. *Holcomb-Great Wall of China Playas.* Holcomb Playa (see Figure 16) is of interest because it is one of two penultimate western points, Cedar Lakes being the other, to which runoff flows from the Bug Scuffle-Grapevine-Sand canyons area during wet years and or major storms. If the playa fills and overtops its sill, water flows into Great Wall of China Playa through Holcomb Channel, and creates a deltafan in the process.[5] Upon drying, the now depigmented (whitish) sand saltates across the playa and adds a white sand component to the Great Wall of China Lunette, which is otherwise dominated by whitish alkali sediment derived from

[5] Mr. Roy Holcomb, long-time area rancher, and resident since 1926, does not recall water ever being in the playa of his namesake (personal communications 1996, 1997). However, the very existence of the playa and its overflow channel and the associated floodflow discharge fan-delta in Great Wall of China Playa clearly indicate that floodwaters have drained to this playa repeatedly. Historic-aged large sand piles and abundant dune trains on Grapevine fan immediately to the east of Holcomb Playa probably have blocked most flow to the playa during Holcomb's tenure in the area.

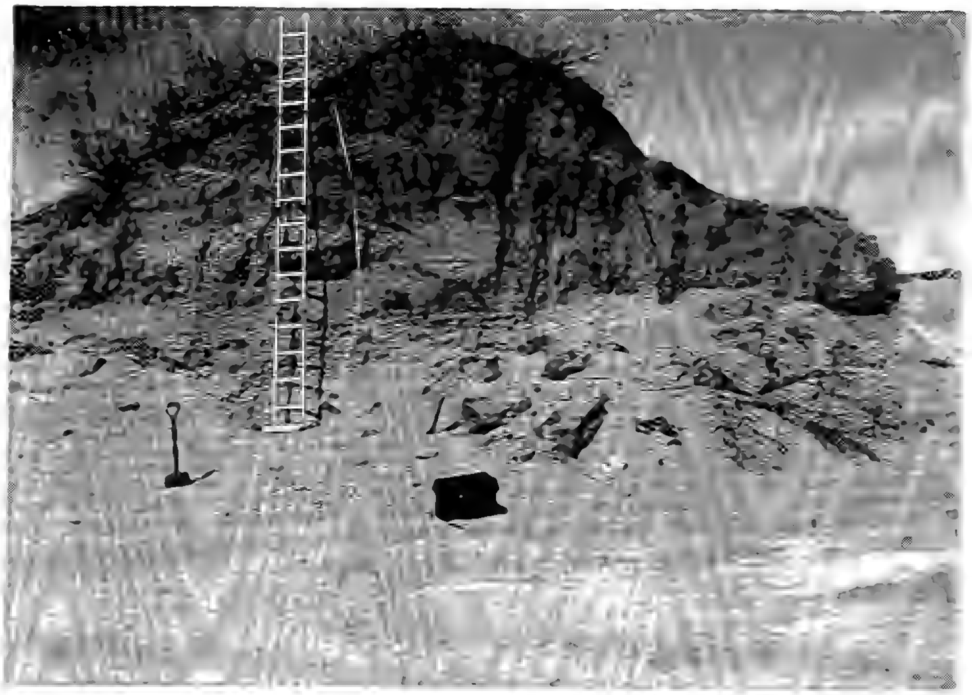


Figure 41. Two views of the BLM Borrow Pit, site 6, 0.3 km west of Highway 54 between mile markers 44 and 45 (6.9 km north of County Road 506). Three eolian sand units, Units 1-3, are present throughout the borrow pit area, which is now also used for motorcycle and ORV recreation.

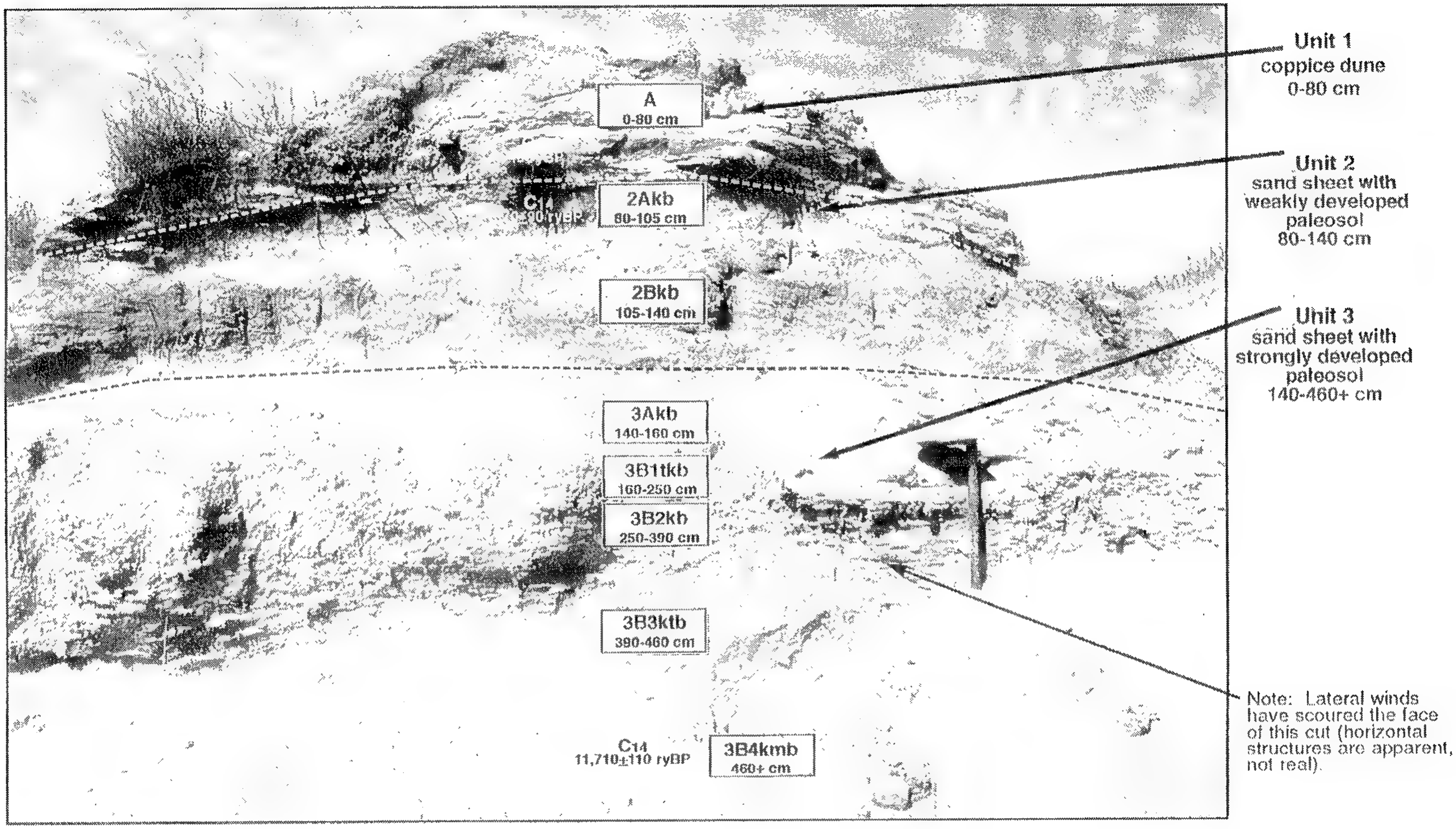


Figure 42. This sand borrow pit, on the west side and adjacent to Highway 54, is 4.3 miles north of County Road 506 between mile markers 44 and 45. Sand accumulation here is one of the thickest in the area and dates well into the Pleistocene. The site was selected for study because the excellent exposures provide insights of Pleistocene and Holocene sand dynamics and chronology for the area north and east of the Jarilla Mountains, including the northern McGregor Range which is just across the highway. Each of the three superposed sand units here expresses varying degrees of soil development that is an approximate measure of age; the topmost unit has an incipient soil, the middle unit shows modest soil development, and the lowermost has strong development. Dashed lines show boundaries of the three sand sheet units.

Table 5
BLM Borrow Pit, Site 6, McGregor Range, New Mexico
Particle Size and Chemical Data

Particle Size Data

Horizon	Depth	Sediment / Percent											Textural Class
		Clay	Silt	Sand	Fine Silt	Coarse Silt	Very Fine Sand	Fine Sand	Medium Sand	Coarse Sand	Very Coarse Sand	Gravel	
1/A	0-10	6.20	7.30	86.50	0.00	7.30	35.40	48.10	2.70	0.20	0.10	0.00	LFS
1/A	10-20	5.90	7.80	86.30	1.50	6.30	29.90	52.70	3.40	0.30	0.00	0.00	LFS
1/A	20-30	5.10	6.20	88.80	0.60	5.60	28.40	53.40	6.40	0.50	0.10	0.00	FS
1/A	30-40	4.50	3.80	91.70	0.20	3.60	24.50	58.80	7.30	1.10	0.00	0.00	FS
1/A	40-50	4.30	3.80	92.00	0.40	3.40	25.60	56.80	8.60	1.00	0.00	0.00	FS
1/A	50-60	4.90	4.40	90.70	0.00	4.40	24.50	58.10	7.10	1.00	0.00	0.00	FS
1/A	60-70	4.80	3.60	91.50	0.00	3.60	21.00	57.70	11.30	1.40	0.00	0.00	FS
1/A	70-80	4.90	2.10	92.90	0.00	2.10	17.50	62.60	11.20	1.60	0.00	0.00	FS
2/2Akb	80-90	5.40	2.40	92.10	0.00	2.40	15.40	57.80	16.50	2.40	0.00	0.00	FS
2/2Akb	90-100	7.60	1.90	90.50	0.00	1.90	14.90	59.20	13.60	2.80	0.00	0.00	FS
2/2Bkb	100-110	5.80	3.60	90.70	2.10	1.50	14.90	55.60	16.90	3.20	0.10	0.00	FS
2/2Bkb	110-120	7.20	2.10	90.70	0.40	1.60	15.20	59.60	13.10	2.70	0.10	0.00	FS
2/2Bkb	120-130	6.80	2.20	90.90	0.70	1.60	17.70	58.60	12.60	2.00	0.00	0.00	FS
2/2Bkb	130-140	7.00	2.30	90.70	0.20	2.10	17.90	60.00	10.70	2.10	0.00	0.00	FS
3/3Akb	140-150	7.10	4.40	88.50	1.50	2.80	19.10	55.00	12.60	1.90	0.00	0.00	LFS
3/3Akb	150-160	8.90	4.30	86.80	1.10	3.20	17.60	55.20	11.70	2.30	0.10	0.00	LFS
3/3B1tkb	160-170	12.50	2.90	84.60	0.70	2.10	13.90	52.10	15.90	2.70	0.00	0.00	LFS
3/3B1tkb	170-180	16.70	2.40	80.90	0.50	1.90	12.60	53.20	12.60	2.40	0.00	0.00	FSL
3/3B1tkb	180-190	16.50	2.90	80.60	1.70	1.10	12.30	51.30	15.00	2.00	0.00	0.00	FSL
3/3B1tkb	190-200	17.60	1.00	81.40	0.50	0.50	10.90	55.20	13.10	2.20	0.10	0.00	FSL
3/3B1tkb	200-210	15.60	0.90	83.60	0.50	0.40	9.70	54.50	17.20	2.20	0.00	0.00	FSL
3/3B1tkb	210-220	13.70	0.90	85.40	0.70	0.20	9.90	59.50	13.80	2.10	0.10	0.00	LFS
3/3B1tkb	220-230	10.60	2.00	87.40	1.80	0.20	11.10	56.60	17.60	2.20	0.00	0.00	LFS
3/3B1tkb	230-240	8.60	1.30	90.10	0.70	0.60	11.30	61.30	15.20	2.40	0.00	0.00	FS
3/3B1tkb	240-250	9.50	1.20	89.30	0.20	1.00	10.70	57.90	18.50	2.30	0.00	0.00	LFS
3/3B2kb	250-260	8.60	1.40	89.90	0.90	0.50	11.60	61.40	14.80	2.10	0.00	0.00	FS
3/3B2kb	260-270	6.90	1.50	91.70	0.20	1.20	12.20	58.00	19.30	2.20	0.00	0.00	FS
3/3B2kb	270-280	5.60	1.30	93.10	0.70	0.70	10.90	63.30	16.40	2.40	0.00	0.00	FS
3/3B2kb	280-290	4.40	2.10	93.40	0.80	1.30	11.50	58.20	21.10	2.50	0.00	0.00	FS
3/3B2kb	290-300	4.30	1.90	93.70	0.60	1.30	11.10	62.90	17.20	2.50	0.00	0.00	FS
3/3B2kb	300-310	3.70	3.00	93.30	1.50	1.50	11.60	59.40	20.00	2.30	0.00	0.00	FS

Table 5 (cont'd)

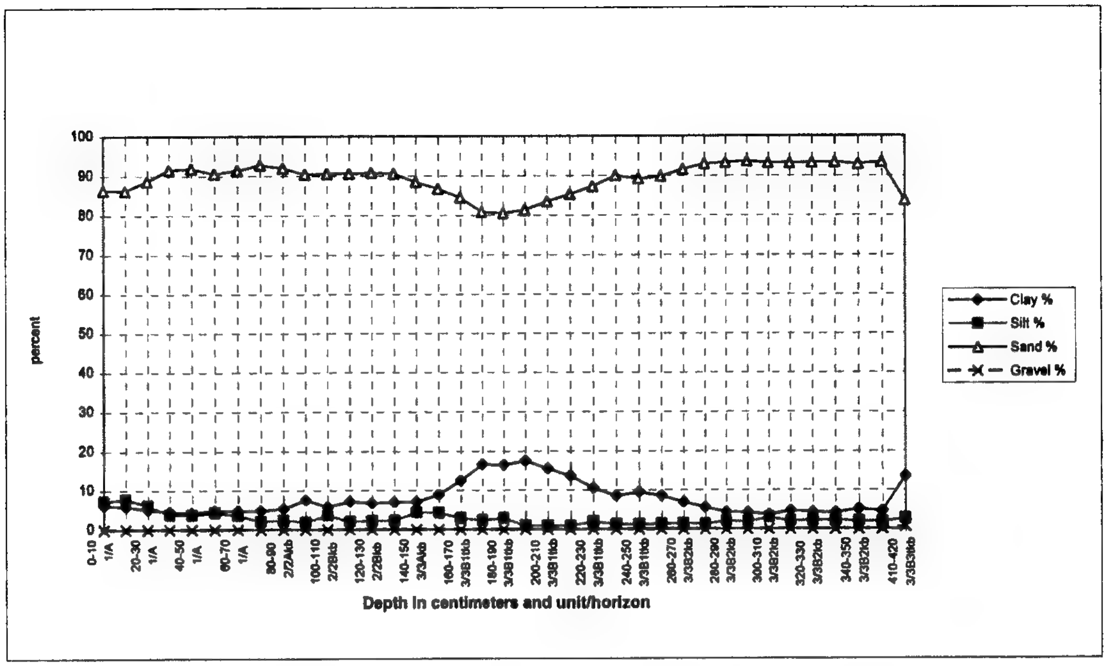
Horizon	Depth	Clay	Silt	Sand	Fine Silt	Coarse Silt	Very Fine Sand	Fine Sand	Medium Sand	Coarse Sand	Very Coarse Sand	Gravel	Textural Class
		Sediment / Percent											
3/3B2kb	310-320	4.70	2.10	93.20	0.60	1.50	11.60	62.20	17.00	2.40	0.00	0.00	FS
3/3B2kb	320-330	4.40	2.20	93.40	0.90	1.40	13.30	59.10	18.70	2.30	0.00	0.00	FS
3/3B2kb	330-340	4.20	2.30	93.50	1.20	1.10	14.20	61.40	15.40	2.50	0.00	0.00	FS
3/3B2kb	340-350	5.10	2.00	93.00	0.60	1.40	15.70	56.10	18.60	2.50	0.00	0.00	FS
3/3B2kb	350-360	4.60	1.90	93.50	0.80	1.00	16.90	58.90	15.10	2.50	0.00	0.00	FS
3/3B3tkb	410-420	13.60	2.70	83.80	0.60	2.10	18.10	54.90	8.90	1.40	0.40	0.70	LFS

Chemical Data

Horizon	Depth	Ca meq/100g	Mg meq/100g	Na meq/100g	K meq/100g	Sum of Bases meq/100g	Acidity meq/100g	Al meq/100g	CEC by sum of cations meq/100g	CEC-7 (NH4OAc) meq/100g	CEC Bases + Al	Al Sat %	Base Sat by sum %	Base Sat by CEC-7 %	Organic Carbon %	Salt pH .01M CaCl2	Water pH
1/A	0-10	10.00	1.20	TR	0.60	11.80	0.70	--	12.50	6.30	--	--	94.00	100.00	0.20	7.30	7.90
1/A	10-20	8.30	0.80	TR	0.40	9.60	0.90	--	10.50	5.80	--	--	91.00	100.00	0.20	7.30	7.90
1/A	20-30	9.00	0.80	0.10	0.20	10.10	1.00	--	11.10	5.60	--	--	91.00	100.00	0.30	7.30	7.50
1/A	30-40	7.10	0.40	TR	0.10	7.60	2.70	--	10.30	5.30	--	--	74.00	100.00	0.30	5.30	5.40
1/A	40-50	4.50	0.40	TR	0.10	5.00	1.80	--	6.80	4.70	--	--	74.00	100.00	0.20	5.70	5.90
1/A	50-60	7.10	0.80	0.10	0.10	8.10	1.60	--	9.70	6.80	--	--	84.00	100.00	0.60	6.30	6.50
1/A	60-70	7.00	0.40	0.10	0.10	7.60	3.20	--	10.80	6.60	--	--	70.00	100.00	0.70	5.20	5.30
1/A	70-80	4.50	0.40	TR	0.10	5.00	2.30	--	7.30	4.80	--	--	68.00	100.00	0.20	5.10	5.30
2/2Akb	80-90	7.10	0.80	0.10	0.30	8.30	0.50	--	8.80	4.50	--	--	94.00	100.00	0.10	6.90	7.30
2/2Akb	90-100	15.40	0.80	0.10	0.20	16.50	0.00	--	16.50	5.60	--	--	100.00	100.00	0.10	7.20	7.60
2/2Bkb	100-110	15.40	1.20	0.10	0.30	17.00	0.30	--	17.30	6.20	--	--	98.00	100.00	0.10	7.30	7.70
2/2Bkb	110-120	10.90	1.20	0.10	0.20	12.40	2.30	--	14.70	6.30	--	--	84.00	100.00	0.10	7.30	7.60
2/2Bkb	120-130	8.30	1.20	0.10	0.20	9.80	0.70	--	10.50	6.00	--	--	93.00	100.00	0.10	7.30	7.60
2/2Bkb	130-140	8.60	1.20	0.20	0.20	10.20	0.00	--	10.20	6.10	--	--	100.00	100.00	0.10	7.30	7.50
3/3Akb	140-150	8.50	1.60	0.20	0.20	10.50	0.00	--	10.50	6.70	--	--	100.00	100.00	0.10	7.30	7.60
3/3Akb	150-160	9.50	2.00	0.30	0.20	12.00	0.00	--	12.00	7.60	--	--	100.00	100.00	0.10	7.30	7.50
3/3B1tkb	160-170	29.00	2.40	0.40	0.20	32.00	0.00	--	32.00	8.80	--	--	100.00	100.00	0.10	7.00	7.20
3/3B1tkb	170-180	43.50	3.50	0.60	0.30	47.90	0.00	--	47.90	10.60	--	--	100.00	100.00	0.20	7.20	7.30
3/3B1tkb	180-190	32.10	3.50	0.60	0.40	36.60	0.00	--	36.60	11.10	--	--	100.00	100.00	0.10	7.30	7.40
3/3B1tkb	190-200	40.90	3.60	0.50	0.40	45.40	0.00	--	45.40	11.30	--	--	100.00	100.00	0.10	7.30	7.40
3/3B1tkb	200-210	37.40	3.20	0.50	0.30	41.40	0.00	--	41.40	10.10	--	--	100.00	100.00	0.10	7.20	7.40
3/3B1tkb	210-220	23.30	3.10	0.50	0.30	27.20	0.00	--	27.20	9.20	--	--	100.00	100.00	TR	7.20	7.40

Table 5 (cont'd)

Horizon	Depth	Ca meq/100g	Mg meq/100g	Na meq/100g	K meg/100g	Sum of Bases meq/100g	Acidity meq/100g	Al meq/100g	CEC by sum of cations meq/100g	CEC-7 (NH4OAc) meq/100g	CEC Bases + Al	Al Sat %	Base Sat by sum %	Base Sat by CEC-7 %	Organic Carbon %	Salt pH .01M CaCl2	Water pH
3/3B1tkb	220-230	16.20	2.50	0.40	0.20	19.30	0.00	–	19.30	8.00	–	–	100.00	100.00	0.10	7.20	7.40
3/3B1tkb	230-240	8.60	2.00	0.30	0.30	11.20	0.00	–	11.20	6.90	–	–	100.00	100.00	TR	7.20	7.50
3/3B1tkb	240-250	10.30	2.00	0.40	0.30	13.00	0.00	–	13.00	6.90	–	–	100.00	100.00	TR	7.20	7.40
3/3B2kb	250-260	9.10	2.00	0.30	0.30	11.70	TR	–	11.70	6.60	–	–	99.00	100.00	TR	7.20	7.60
3/3B2kb	260-270	8.60	1.60	0.30	0.20	10.70	0.00	–	10.70	5.40	–	–	100.00	100.00	TR	7.20	7.60
3/3B2kb	270-280	14.10	1.20	0.30	0.20	15.80	0.00	–	15.80	4.60	–	–	100.00	100.00	TR	7.20	7.60
3/3B2kb	280-290	3.80	1.20	0.30	0.20	5.50	0.00	–	5.50	4.10	–	–	100.00	100.00	TR	7.20	7.60
3/3B2kb	290-300	3.30	1.20	0.30	0.20	5.00	0.40	–	5.40	4.10	–	–	93.00	100.00	TR	7.20	7.50
3/3B2kb	300-310	15.80	1.20	0.40	0.20	17.60	0.00	–	17.60	4.20	–	–	100.00	100.00	TR	7.20	7.50
3/3B2kb	310-320	8.30	1.20	0.40	0.20	10.20	0.10	–	10.30	4.20	–	–	99.00	100.00	TR	7.20	7.30
3/3B2kb	320-330	6.60	1.20	0.40	0.20	8.30	0.00	–	8.30	4.40	–	–	100.00	100.00	0.10	7.20	7.40
3/3B2kb	330-340	4.60	1.20	0.40	0.20	6.40	0.00	–	6.40	4.00	–	–	100.00	100.00	–	7.20	7.60
3/3B2kb	340-350	4.30	1.20	0.30	0.20	6.00	0.00	–	6.00	4.20	–	–	100.00	100.00	TR	7.30	7.60
3/3B2kb	350-360	9.80	1.20	0.60	0.20	11.90	0.00	–	11.90	4.20	–	–	100.00	100.00	TR	7.20	7.60
3/3B3tkb	410-420	40.60	1.60	0.10	0.10	42.40	0.00	–	42.40	3.00	–	–	100.00	100.00	0.10	7.30	7.50



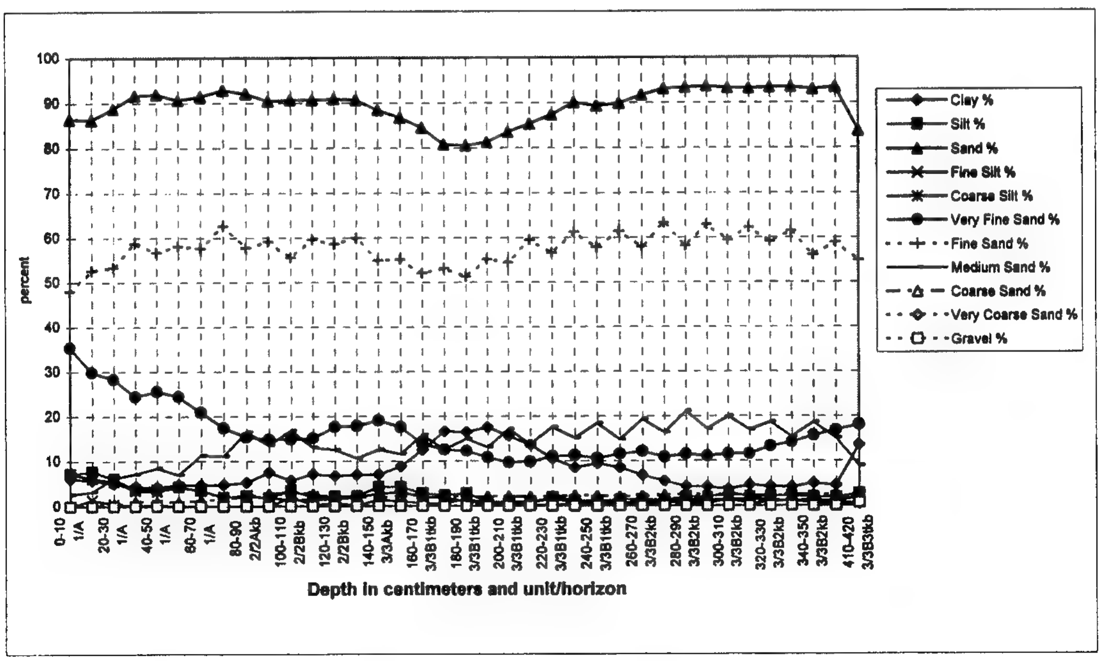
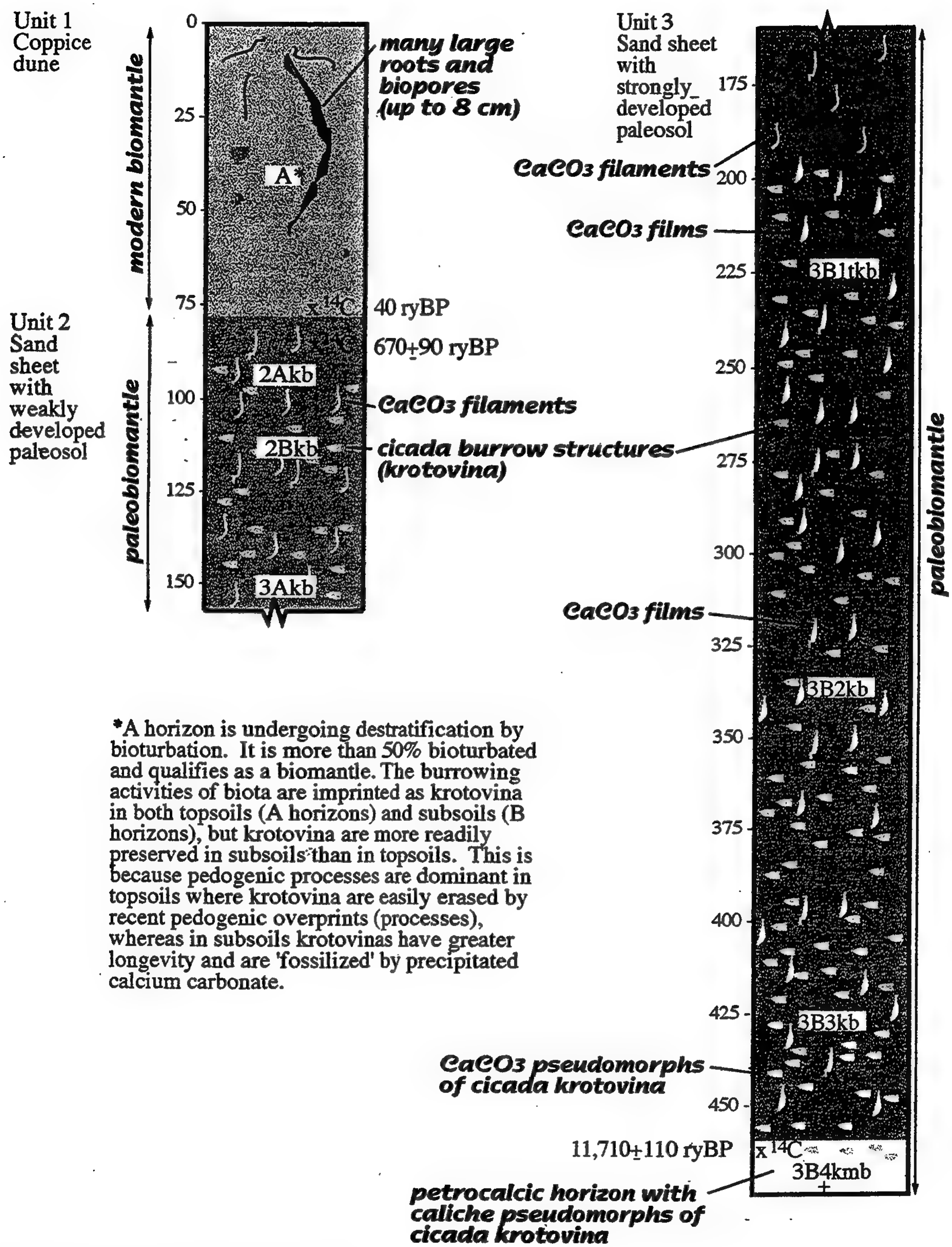


Figure 43. BLM Borrow Pit, site 6, on footslopes of Grapevine Canyon fan, northwestern McGregor Range, depth functions of four (upper) and 11 (lower) particle sizes.



*A horizon is undergoing destratification by bioturbation. It is more than 50% bioturbated and qualifies as a biomantle. The burrowing activities of biota are imprinted as krotovina in both topsoils (A horizons) and subsoils (B horizons), but krotovina are more readily preserved in subsoils than in topsoils. This is because pedogenic processes are dominant in topsoils where krotovina are easily erased by recent pedogenic overprints (processes), whereas in subsoils krotovinas have greater longevity and are 'fossilized' by precipitated calcium carbonate.

Figure 44. Profile schematic of BLM Borrow Pit, site 6.

Figure 45 Photos taken along a dirt track between Highway 54 and Moody Tank in the Moody Lowlands north of the Jarilla Mountains. In the upper photo, field assistant D. N. Johnson is pointing to calichefied krotovina exposed in the roadbed. The krotovina are in the upper part of a petrocalcic horizon. This petrocalcic horizon is the basal portion of an eroded soil that is correlative with the buried Unit 3 soil at the BLM Borrow Pit, site 6. This soil, though buried at the BLM Borrow Pit, is surface exposed in places across the Moody Lowlands, as here in this road. The lower photo is a close-up of the calichefied cicada burrow infillings (calcified cicada krotovina).

surface-precipitated alkali on the playa floor (the Great Wall of China Playa is an evaporation-precipitation-deflation [salina] type playa, see Glossary and Playas and Temporary Lakes section above). Some sand migrates farther east (downwind) beyond the lunette, back onto McGregor land and adds to the light-colored dunes in the area, another source being the alkali component itself. It is worthy of note that this sand-alkali-precipitation-eolian cycle will cease in the future, for The Great Wall of China Playa is being slowly overrun by coppiced dune sheets advancing from the southwest. Probably half of this large playa is now buried by these advancing reddish sands (Figure 46).

3. *Railroad Gypsite, Site 7.* This site, at Dunes Siding on the Southern Pacific Railroad (formerly El Paso and Northeastern), exemplifies the strange earthy semiparabolic gypsite dune lobes that have advanced into northwestern McGregor from the Cedar Lakes alkali playas and flats area north and east of the Great Wall of China Lunette (see Figure 18; DSG/Pl/A1 mapping unit, Deadman quad). These wasted gypsite lobes can be discerned in plain view on high altitude photos (see Figure 16) and in the close-up (Figure 47).[6] The description for the profile is in Appendix D, and a profile schematice is shown in Figure 48. The physical and chemical data are in Table 6, and graphs of particle size depth functions are in Figure 49. Table 7 presents the preliminary results of the lunette sample analysis.

The gypsite lobes have scattered surface mounds of ants, gophers, and badgers here and there, but krotovina were not seen in the exposures along the railroad tracks or in the described pedon. The reason is that these immature profiles are a uniform white color throughout, and krotovina are notable only when there is some degree of color differentiation between horizons (Johnson 1989).

The alkali-gypsite playas and flats immediately west of the lobate gypsite dunes, called Cedar Lakes by local residents because salt cedar trees are present, periodically flood with water from Bug Scuffle and Grapevine canyons "about every ten years or so" according to Mr. Roy Holcomb (personal communication 1996, 1997), who has observed the process for 70 years. When these lakes dessicate, the alkali residue may deflate downwind (east) and episodically add alkali to the gypsite lobes.

Cox, Wilde, and Sand Playas, and Other Nearby Sites

Seven sites were studied at various levels of detail in this area, which collectively illuminate the evolution of this key part of McGregor.

1. *Cox and Salt Cedar Playas.* The gypsite flats around Cox Well contain several playas, one of which is Cox Playa at the well itself (see Figure 16; mapping unit DSG/A1/Pl, Pipeline quad). It is a temporary playa that overflows to lower Salt Cedar Playa several kilometers southwest. If the Jarilla bolson receives exceptional runoff, however, all these playas coalesce into a larger Lake Jarilla. This essentially happened in 1941 (see Temporary Lakes and Playas section above). Salt Cedar Playa is another gypsite playa, the lowest one in the Bolson, and is thus a permanent playa. The presence of salt cedars around its periphery suggest a perched water table, or at least enough seasonal moisture and runon retained in the sediments to sustain the shrubs.

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[6] It is difficult to find a clear and unequivocal modern analog in the area today that conforms to the gypsite landform shown in Figure 47. It seems not to have been a comminuted selenite gypsum dune, like the White Sands National Monument dunes that emanate from Lake Lucero, though this cannot be ruled out entirely. It seems more likely that it was an eolian-entrained earthy-type dune derived as precipitated gypsum from either the floor of the Great Wall of China Playa, or more likely from one of several smaller playas on its northeastern periphery (e.g., Cedar Lakes). Whatever, it is now a wasted earthy mass whose soil profile is nondistinct, immature, and relatively unhorizonated. It is included in Derr (1981:map 16) in the Holloman-Reeves Association, though the profile where described does not exactly fit the descriptions of either of those two series (see Appendix C).

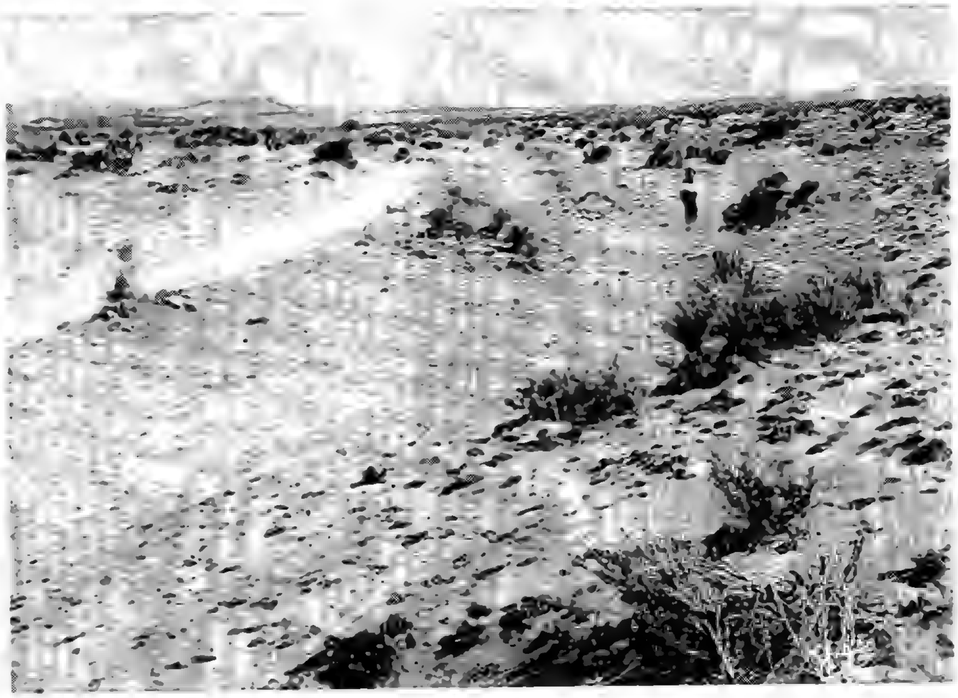


Figure 46 Two views of the Great Wall of China Playa area that were taken between Highway 54 and Lone Butte, north of the Jarilla Mountains, New Mexico. Upper photo: looking east-southeast, taken on the west side of the southern part of the Great Wall of China Lunette. The human figure is standing in Holcomb Channel, an overflow channel that sheds storm waters from Holcomb Playa and Grapevine Canyon alluvial fan into the Great Wall of China Playa. Lower photo: a view looking east-southeast across Holcomb Playa to Highway 54 (note car) and the Sacramento Mountains (left) and Otero Mesa (right) beyond. This photo was taken from atop the southern end of the Great Wall of China Lunette.

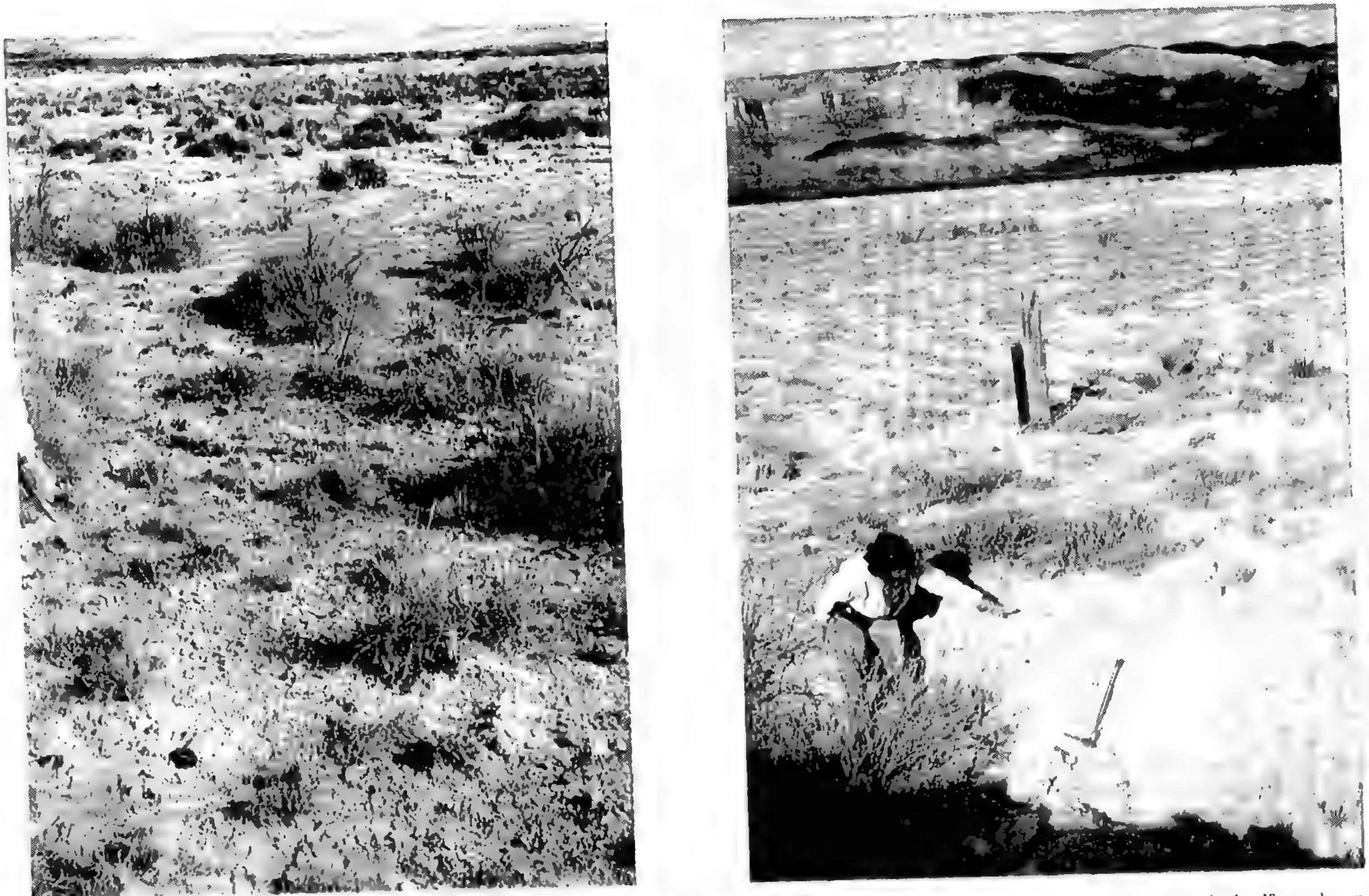


Figure 47. Two views of the area around Railroad Gypsite, site 7. Gypsite Flats, at Dunes Railroad Siding, northwestern McGregor Range, New Mexico. The gypsite landform shown in the photos was apparently once a dune, for its dunal lobate shape is apparent on Figure 16. It is, however, difficult to find a clear and unequivocal modern analog in the area today. It seems not to have been a comminuted selenite gypsum dune, like the White Sands National Monument dunes that emanate from Lake Lucero, though this cannot be ruled out entirely. It seems more likely that it was an eolian-entrained earthy-type dune derived as precipitated gypsum from either the floor of the Great Wall of China Playa or, more likely, from one of several smaller playas on its northeastern periphery (e.g., Cedar Lakes). Nonetheless, it is now a wasted earthy mass whose soil profile is nondistinct, immature, and relatively unhorizonated. It is included in Derr (1981:map 16) in the Holloman-Reeves Association, though the profile where described does not exactly fit the descriptions of either of those two series (see Appendix C).

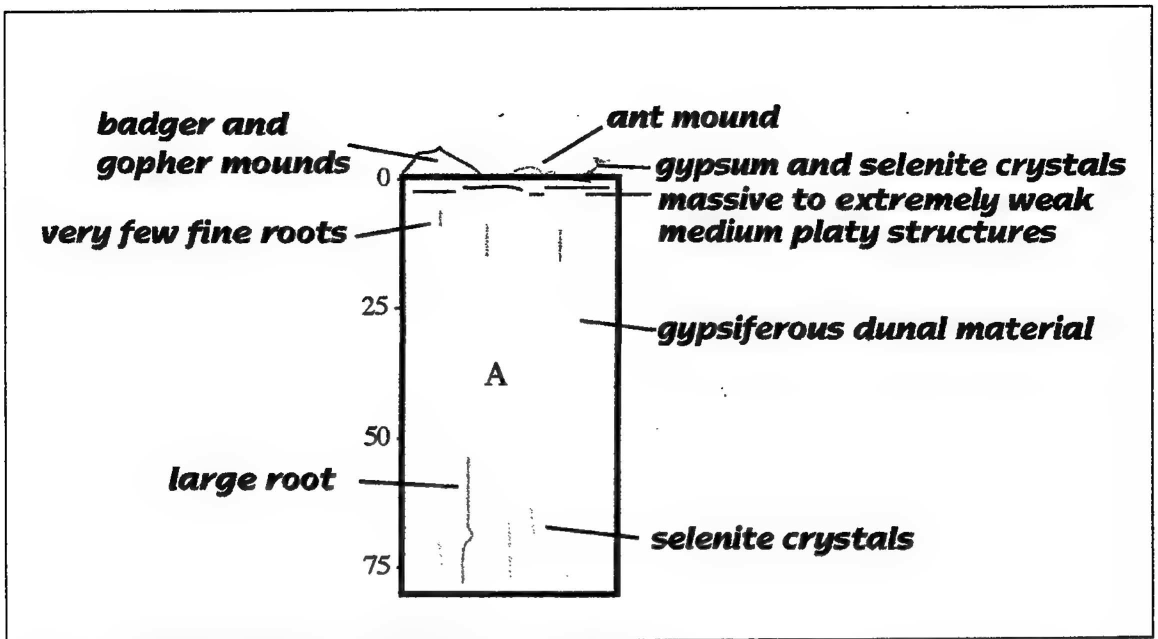


Figure 48. Profile schematic of the gypsite profile at Dunes Railroad Siding of the Southern Pacific Railroad (formerly El Paso and Northeastern Railroad; cf., Figures 47 and 49; see Table 6).

Both Salt Cedar and Cox playas have associated gypsite lunettes on their downwind (north-northeast) sides, which appear as small versions of the huge lunettes at the Lone Butte and Great Wall of China playas. The main source of the alkali is probably eolian dust that blankets the landscape as fallout, which then is concentrated in the playas via runoff. Some gypsum probably also derives as runoff from weathered Permian gypsum-bearing beds that outcrop in the southern Sacramento Mountains and northern Otero Mesa. Figures 50 and 51 show several views of Cox Playa, its alkali lunette, the animals that impact the area, and the alkali-adapted vegetation that grows on the lunette.

2. *Wilde and Sand Playas, Sites 14 and 10.* Wilde Playa, site 14, is located about 1 km southwest of Wilde Well (DS/A1 mapping unit, Wilde Tank quad). It is a temporary playa created when the historic dune train that abuts it on the west migrated up from the Jarilla Gap area and dammed the west-flowing drainage on the alluvial fan coming from the Otero Escarpment (see Figure 15). Because the dune train occupies the lowest level, Wilde Playa formed on the lower toeslope of the alluvial fan. An abbreviated description was made of one pedon in the backhoe pit dug on the playa, which appears representative for all pedons exposed in the pit (see Appendix D). Figure 52 is a closeup view of the described profile. The playa sediments are 85 cm thick and overlie a preplaya sheet sand (presumably eolian in origin because of its good sorting, as opposed to alluvial). Inasmuch as soil development in the buried sheet sand is minimal, the sheet sand was probably still forming and mobile at time of burial. Since 85 cm of playa sediments could conceivably be deposited in a few megafloods over several decades, the stratigraphy here suggests that both the buried dune sheet and the playa sediments are young, possibly historic, and that the pre-European (1880s) settlement surface possibly lies below the bottom of the backhoe pit. That sedimentation in the Jarilla Bolson can be so historically rapid is supported by the sediment-soil profiles exposed in Sand Playa, site 10, near Benton Well several kilometers to the south.

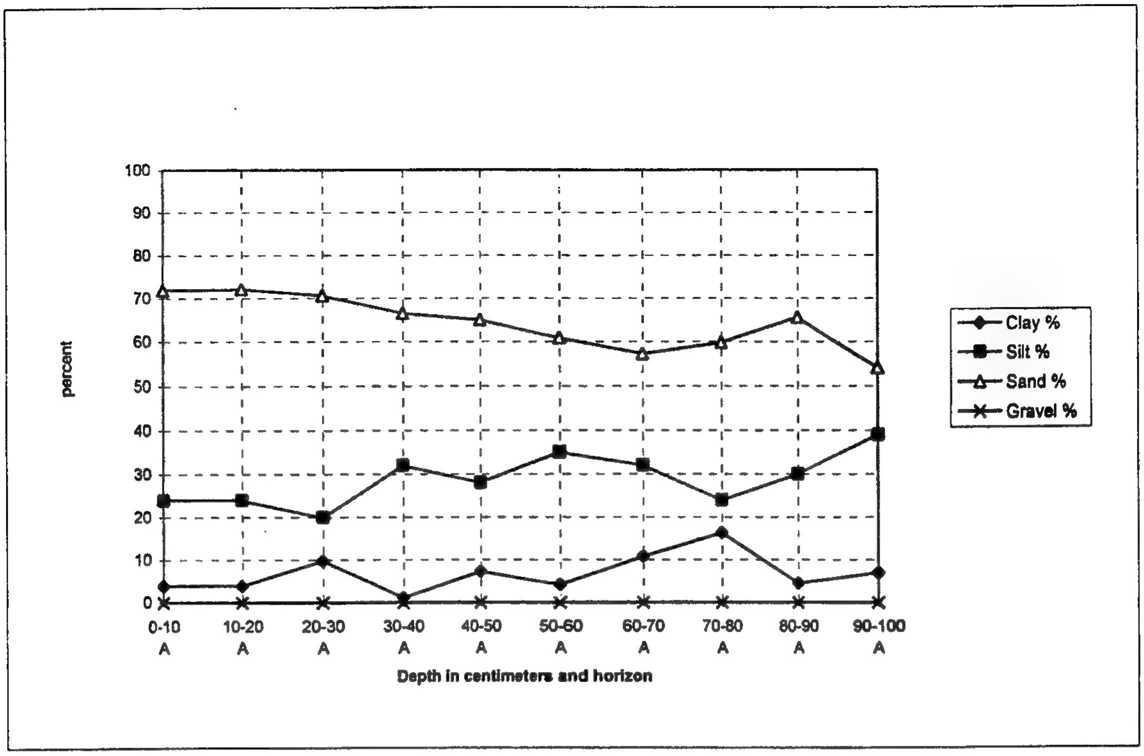
Table 6
Railroad Gypsite, Site 7, McGregor Range, New Mexico
Particle Size and Chemical Data

Particle Size Data

Horizon	Depth	Clay	Silt	Sand	Fine Silt	Coarse Silt	Very Fine Sand	Fine Sand	Medium Sand	Coarse Sand	Very Coarse Sand	Gravel	Textural Class
		Sediment / Percent											
A	0-10	3.90	24.00	72.00	3.30	20.70	5.70	26.50	11.20	19.80	8.70	0.00	COSL
A	10-20	3.90	24.00	72.20	3.40	20.40	5.00	24.90	8.90	21.30	12.10	0.00	COSL
A	20-30	9.80	20.00	70.70	12.50	7.10	3.20	23.60	13.00	21.50	9.30	0.00	COSL
A	30-40	1.10	32.00	66.60	1.10	31.10	3.60	23.00	9.00	20.50	10.60	0.00	COSL
A	40-50	7.30	28.00	65.10	8.00	19.60	2.20	17.50	11.70	23.50	10.20	0.00	COSL
A	50-60	4.20	35.00	60.90	17.50	17.40	3.80	30.90	8.70	13.90	3.60	0.00	FSL
A	60-70	10.80	32.00	57.30	9.20	22.70	22.60	26.90	4.60	2.30	0.90	0.00	SL
A	70-80	16.40	24.00	59.90	7.30	16.50	14.40	31.10	7.30	6.30	0.80	0.00	FSL
A	80-90	4.50	30.00	65.70	10.70	19.10	6.90	25.60	13.10	17.00	3.00	0.00	MSL
A	90-100	7.00	39.00	54.20	13.20	25.60	10.80	25.60	7.10	9.70	1.00	0.00	FSL

Chemical Data

Horizon	Depth	Ca meq/100g	Mg meq/100g	Na meq/100g	K meg/100g	Sum of Bases meq/100g	Acidity meq/100g	Al meq/100g	CEC by sum of cations meq/100g	CEC-7 (NH4OAc) meq/100g	CEC Bases + Al	Al Sat %	Base Sat by sum %	Base Sat by CEC-7 %	Organic Carbon %	Salt pH .01M CaCl2	Water pH
A	0-10	161.00	0.80	0.10	0.10	162.00	0.00	--	162.00	1.80	--	--	100.00	100.00	0.20	6.90	7.10
A	10-20	152.00	1.20	0.10	TR	153.00	0.30	--	154.00	2.00	--	--	100.00	100.00	0.10	7.00	7.20
A	20-30	161.00	2.90	0.10	TR	164.00	0.20	--	164.00	2.40	--	--	100.00	100.00	0.10	7.10	7.30
A	30-40	161.00	2.90	0.20	TR	165.00	0.80	--	165.00	2.50	--	--	100.00	100.00	0.10	7.20	7.30
A	40-50	160.00	4.00	0.20	0.10	164.00	0.50	--	165.00	2.80	--	--	100.00	100.00	0.10	7.20	7.30
A	50-60	159.00	5.10	0.20	0.10	164.00	0.70	--	165.00	3.10	--	--	100.00	100.00	0.10	7.20	7.40
A	60-70	156.00	4.00	0.10	0.10	160.00	0.40	--	161.00	2.80	--	--	100.00	100.00	0.10	7.20	7.40
A	70-80	157.00	3.70	0.20	TR	161.00	0.30	--	162.00	2.00	--	--	100.00	100.00	0.10	7.20	7.40
A	80-90	152.00	3.20	0.10	TR	155.00	0.70	--	156.00	1.60	--	--	100.00	100.00	0.10	7.20	7.40
A	90-100	157.00	3.20	0.10	TR	160.00	0.90	--	161.00	1.20	--	--	99.00	100.00	0.10	7.20	7.40



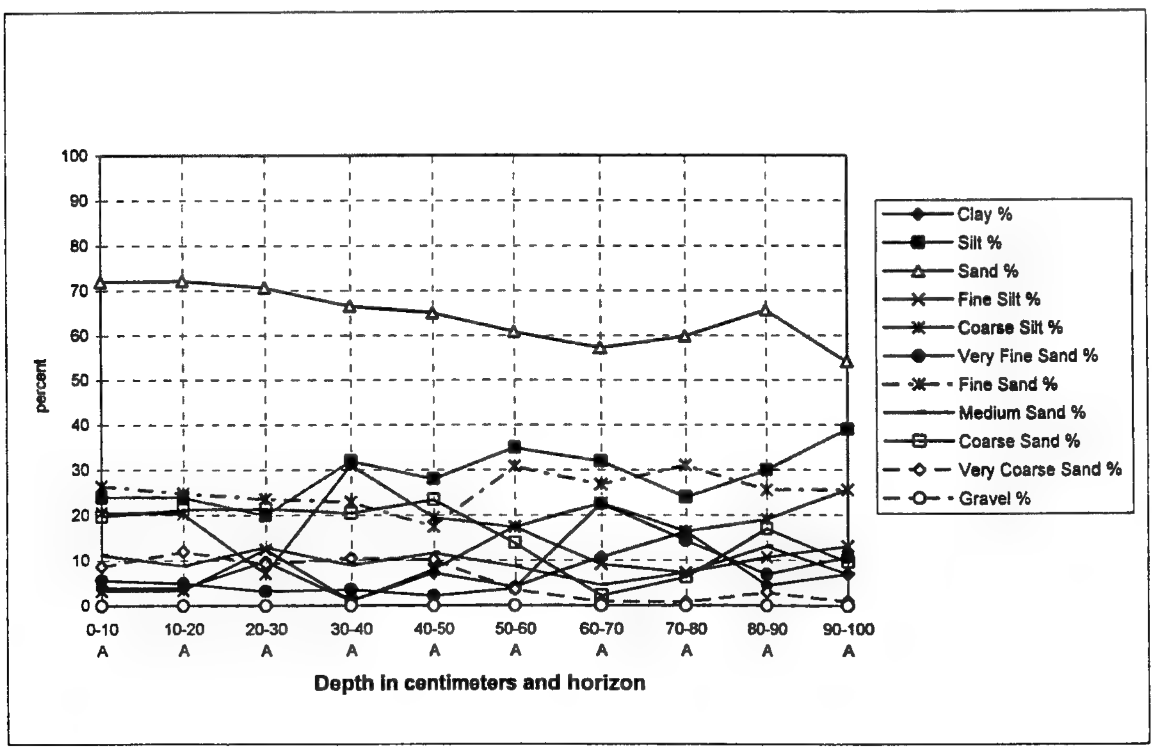


Figure 49. Railroad Gypsite, site 7, depth functions of four (upper) and 11 (lower) particle sizes (no gravels were present in these eolian sediments; data from Table 6).

Table 7
Lunette Samples, Preliminary Results

Sample	Analysis # = / Core = / Depth =	R20938 Jobes Quarry surface	R20928 Ft. Bliss 0-10	R20929 Ft. Bliss 10-20	R20930 Ft. Bliss 20-30	R20931 Ft. Bliss 30-40	R20932 Ft. Bliss 40-50	R20933 Ft. Bliss 50-60	R20934 Ft. Bliss 60-70	R20935 Ft. Bliss 70-80	R20936 Ft. Bliss 80-90	R20937 Ft. Bliss 90-100
Total Carbon	%	2.47	0.54	0.49	0.62	0.68	0.56	0.94	0.68	0.70	0.59	0.55
Inorganic Carbon	%	0.99	0.39	0.27	0.44	0.46	0.32	0.68	0.44	0.47	0.37	0.37
Organic Carbon	%	1.48	0.15	0.22	0.18	0.22	0.24	0.26	0.24	0.23	0.22	0.18
Silicon Dioxide	%	10.06	4.63	8.77	11.98	12.15	9.17	9.24	9.69	7.26	6.16	3.89
Aluminum Oxide	%	1.59	0.47	0.69	1.30	0.91	0.74	0.64	0.66	0.59	0.52	0.64
Iron Oxide	%	0.18	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Iron Oxide (4)	%	0.35	0.09									
Calcium Oxide	%	28.41	38.72	36.24	34.45	34.29	35.86	35.75	35.53	37.09	37.60	38.64
Magnesium Oxide	%	3.80	0.20	0.71	1.57	1.55	1.59	2.38	1.87	1.45	1.10	0.94
Potassium Oxide	%	0.29	0.13	0.22	0.27	0.29	0.21	0.19	0.21	0.16	0.15	0.10
Potassium Oxide (4)	%	0.28	0.11									
Sodium Oxide	%	3.66	0.10	0.15	0.17	0.20	0.14	0.16	0.14	0.13	0.13	0.09
Sodium Oxide (4)	%	5.36	0.06									
Titanium Oxide	%	0.07	0.03	0.03	0.05	0.04	0.04	0.03	0.03	0.03	0.03	0.02
Phosphorus Pentoxide	%	0.10	0.02	0.01	0.02	0.04	0.01	0.01	0.01	0.01	0.01	0.01
Manganese Oxide	%	0.02	<0.01	<0.01	0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.01
Sulfur Trioxide	%	36.63	51.62	49.18	45.70	45.51	48.45	46.00	46.95	49.22	50.22	52.27
H_2O	%	6.14	18.17	17.68	17.11	16.72	17.92	17.01	17.08	18.13	18.03	18.94
Antimony (4)	ppm	0.30	<0.10									
Arsenic (4)	ppm	2.00	0.70									
Barium	ppm	50.00	<10.00	40	<10	9	<10	<10	16	<10	<10	<10
Barium (4)	ppm	162.00	36.00									
Bromine (4)	ppm	25.00	1.80									
Chromium (4)	ppm	3.40	1.20									
Cobalt (4)	ppm	2.10	1.70									
Cesium (4)	ppm	0.61	0.31									
Europium (4)	ppm	0.11	0.06									
Gallium (4)	ppm	<3.00	<1.00									
Hafnium (4)	ppm	1.50	0.20									
Lanthanum (4)	ppm	3.60	0.50									
Molybdenum (4)	ppm	<16.00	<4.00									

Table 7 (cont'd)

Sample	Analysis # = Core = Depth =	R20938 Jobes Quarry surface	R20928 Ft. Bliss 0-10	R20929 Ft. Bliss 10-20	R20930 Ft. Bliss 20-30	R20931 Ft. Bliss 30-40	R20932 Ft. Bliss 40-50	R20933 Ft. Bliss 50-60	R20934 Ft. Bliss 60-70	R20935 Ft. Bliss 70-80	R20936 Ft. Bliss 80-90	R20937 Ft. Bliss 90-100
Nickel (4)	ppm	<3.00	<3.00									
Rubidum (4)	ppm	12.60	2.00									
Samarium (4)	ppm	0.80	0.10									
Scandium (4)	ppm	0.70	0.20									
Selenium (4)	ppm	0.60	<0.50									
Strontium	ppm	2,578	2,907	4,706	4,849	4,875	4,572	2,051	1,860	1,921	2,320	2,029
Tantalum (4)	ppm	0.08	<0.01									
Thorium (4)	ppm	1.10	0.20									
Tungsten (4)	ppm	<1.40	<0.50									
Uranium (4)	ppm	8.60	<1.00									
Zinc (4)	ppm	6.40	1.80									
Zirconium	ppm	119.00	102.00	207	227	228	214	62	44	55	72	52

( ) = XRF; (1) = EDX, (2) = AA,; (4) = INAA

Sand Playa is another temporary playa, even more temporary than Wilde Playa, that lies about 0.6 km south-southeast of Benton Well (Pl/A1 mapping unit, Orogrande N quad). It formed in a slight depression in the sand sheet that underlies the area, and doubtless overflows to the west into the lower lying, and much larger, Benton Playa when it receives any substantial runon (see Figure 15). The abbreviated description of one pedon in the backhoe pit that was dug is in Appendix D. Figure 53 shows the stratigraphic relationships in the pit, which are 78 cm of playa sediments that bury a sand sheet (presumably of eolian origin because of its good sorting, as opposed to an alluvial origin which would typically have mixed particle sizes). Note that an artifact (fire-cracked rock) is present at 1.3 m depth within the sand sheet. Presumably the artifact is a dropped manuport inasmuch as it lies in a sand sheet and could not have been blown in. A buried site at this level could also be in nearby unexposed pedons.

3. *Wilde Missile Dump, Cactus, and Permian Sandstone/Limestone Sites*. These three sites are discussed together because they lie in similar positions along the footslope-toeslope fan aprons on the east side of the Jarilla Bolson, and all three sites are located on the Wilde Tank quad. They are also only several kilometers apart in a north-south direction.

The Wilde Missile Dump site, site 13, is about 0.5 km east-southeast of Wilde Well on the road to Otero escarpment near a pile of missile flotsam and jetsam (A1 mapping unit, Wilde Tank quad). The abbreviated sediment-soil description is in Appendix D, and a photograph of the site is shown in Figure 54. Here some 82 cm of calcareous toeslope fine-fraction sediment overlies a presumed eolian sand sheet exposed at a depth of between 82 and 200 cm (to the base of the backhoe pit). The stratigraphy here is a near image of sites 10 and 14 at Sand and Wilde playas. The stratigraphy shows that the A horizon pinkish color derives from the Permian redbeds that outcrop along the escarpment. It also shows that sheet sand formerly migrated across this surface, presumably from the southwest, then became buried by toeslope alluvial fan sediments from the eastern escarpment. The brownish-reddish eolian sand is derived from eroded sandy soils upwind (southwest)

Figure 50. Cox Playa, east of Highway 54 and south of County Road 506 within the Bolson Bottom Complex (BBC) mapping unit in Jarilla Depression (see Figure 18). This playa, and its lunette, are gypsiferous. The upper photo shows the playa looking northeast from Cox Well, with its gypsiferous lunette in the distance and downwind. Note human figure standing on lunette for scale (arrow). Note also the cracked and curled surface crust caused by desiccation of moist playa sediment. Note that stock animals have disturbed the surface, a disturbance process that was probably also common but involving indigenous animals during prehistoric time. Such animal-caused disturbance renders the playa floor susceptible to eolian deflation where sediment is blown onto the lunette. The lower photo offers a view from the top of the Cox Playa lunette looking southwest towards Cox Well and its windmill, with the Jarilla Mountains as a backdrop. This photo also shows the burrowing effects of rodents in the foreground (large mound with holes), and badgers at lower right (two partially infilled badger burrows and wasted mounds). Bioturbation by rodents and badgers impacts all surfaces of the McGregor Range, including such alkali gypsite lands as shown here.

Figure 51. Photos of the Great Wall of China lunette. Upper photo taken looking west-northwest (San Andres Mountains on horizon), showing gypsite-alkali adapted vegetation, including yucca and a peculiar and distinctive circular-growing grass species. A fresh badger-burrow and mound are visible in the lower photo.

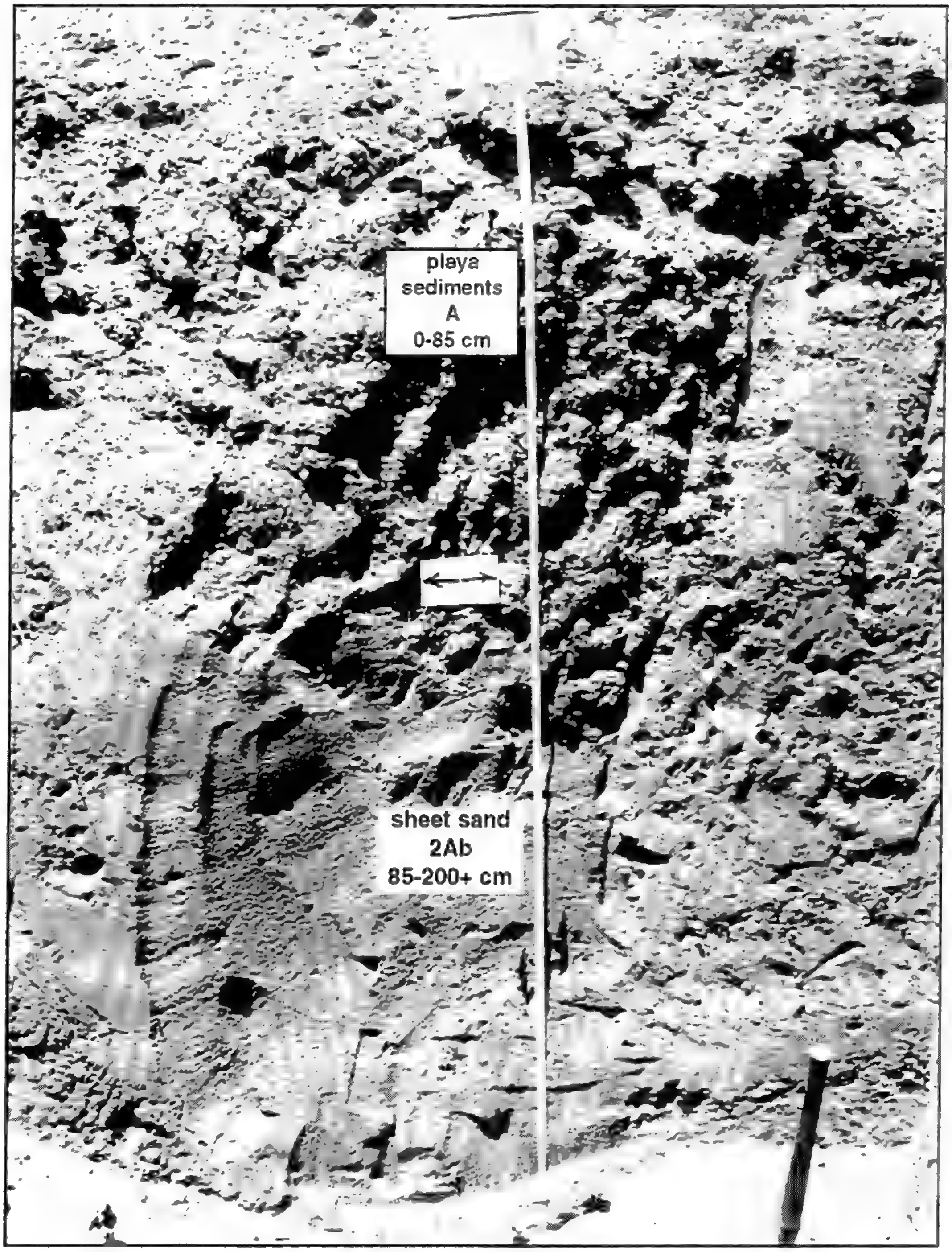


Figure 52. Wilde Playa, site 14, sediment profile. Playa sediments are present above horizontal double-tipped arrow, and sheet dune sand is below the arrow (note shovel marks in sand at lower left). This profile is similar to site 10 (Benton Well) and site 13 (Wilde Missile Dump), both also on the distal toeslope of the fan-apron that originates along the Otero Escarpment on the east side of the basin. Wilde Playa formed as a consequence of drainage blockage against the massive sand train that clogs this part of the Jarilla Bolson. This dune train is slowly migrating to the north-northeast. Many ephemeral playas in the Jarilla Bolson, like Wilde Playa, doubtless form and then become buried by sand, a process that has probably repeated itself many times throughout the recent geologic past.

Figure 53. Sand Playa, site 10, soil profile. This playa occupies the lower toeslope of the fan complex that drains the eastern side of the Jarilla Bolson (the lowest part of the depression is several hundred meters west-northwest of this playa). The playa has an associated sandy lunette dune on its north-northeast periphery. The playa soil profiles are similar to those observed at sites 13 (Wilde Missile Dump) and 14 (Wilde Playa). A fire-cracked rock manuport was encountered at 1.3 m depth in the east wall of this pit. The horizontal line scratched into the pit wall is the A/2Ab boundary.

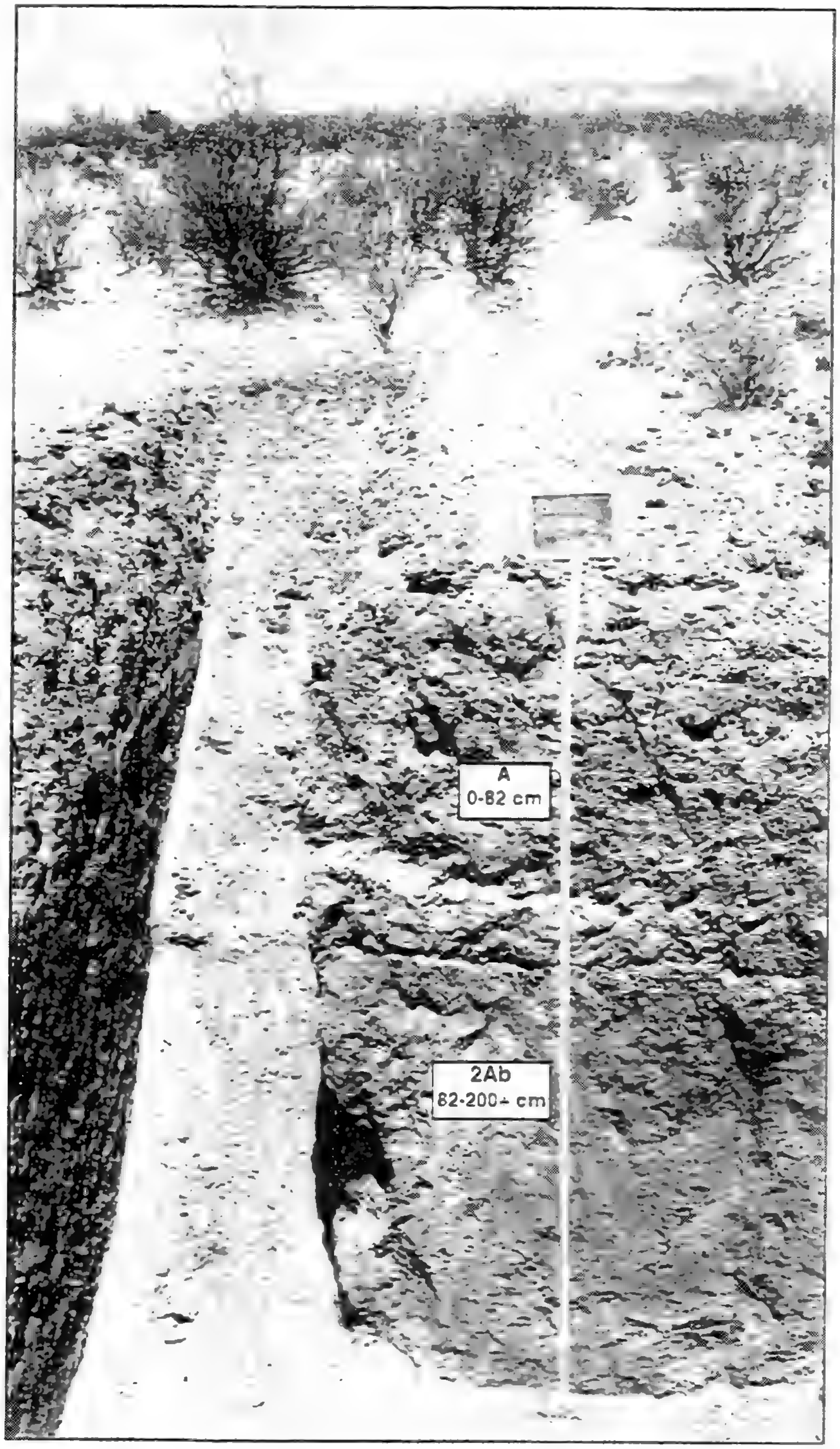


Figure 54. Wilde Missile Dump, site 13, stratigraphy. This site is in the Jarilla Bolson on the toeslope of the west-draining (eastern) alluvial fan-apron that originates along the Otero Escarpment to the east. The stratigraphy, where 82 cm of toeslope sediment overlies sheet dune sand (the boundary at the horizontal line) indicates that sand formerly migrated across this surface, then became buried under toeslope fan sediments emanating from the east. The brownish-reddish sand is derived partly from soil erosion to the southwest (upwind) and partly from reddish Permian sandstones along the Otero Escarpment.

and from reddish Permian sandstones along the Otero escarpment that washed into the Bolson, then wind-winnowed. The buried sand sheet here, and the buried sand sheets of nearby Sand and Wilde playas, demonstrate how sand is permanently removed from the Tularosa Basin sand cycle via burial by alluviation (see Axiom 9 in Introduction).

The Cactus site, site 15, lies just off the road that runs from Wilde Tank to Lee and Wright tanks and the Old Wright Place (A1 mapping unit, Wilde Tank quad). It lies on the mid-toeslope of the alluvial fan that drains from the east. The full sediment-soil description is in Appendix D, Figure 55 is a photo of the described pedon taken in the backhoe pit, particle size and chemical data are in Table 8, graphs showing depth functions of particle size are in Figure 56, and a profile schematic is shown in Figure 57. There is a notable reddish-pinkish tint to the sediments in this pit, the same tint that typifies all the sediments in the immediate area and upslope (east) to the obvious place of origin of the pinkish color—the Permian bedrock that outcrops near the Old Wright Place (see Figure 16 and Wilde Tank quad). Badger mounds on the surface in which petrocalcic chunks occur prove that these animals penetrate the petrocalcic horizon, as do badgers at the Sulphur and Stone School sites (sites 2 and 42) and all across Otero Mesa (discussed below). The platy A1 horizon here and in most soils on McGregor reflects recent surface sheetwash activity. The A2, Bk1, and Bk2 horizons here are strongly bioturbated by insects, yet horizon differentiation is still more or less displayed. The 'rubbleized' or nodular caliche zone defined by the Bk2 horizon exhibits zones where some pebbles are horizontally oriented, indicating that stratification is partly preserved, but in other places the stones are tipped randomly, indicating that the Bk2 horizon is partly mixed by bioturbation. Cicada-like burrows are subtle but abundant in the A2 and Bk horizons. Clusters of rodent/rabbit-like fecal pellets in the A2 and Bk1 horizons indicate bioturbation (burrowing). Finally, the top of the petrocalcic (Bkm) horizon appears to be breaking up, possibly via recurrent badger burrowing from above; few fine roots penetrate these massive, intermittently ruptured, caliche-cemented platy zones.

About 2 km north of Cactus site (site 15) is the Permian Sandstone/Limestone site, site 16, (also A1 mapping unit, Wild Tank quad). The full description is in Appendix D, a photo of the profile is shown in Figure 58, the chemical and particle size data are in Table 9, and the profile schematic is in Figure 59. The site is named for the gravelly components of this fan toeslope that are a mixture of both redbed sandstone and grayish limestone derived from Permian rocks along the Otero Escarpment. The reddish sandstone clasts are friable and incompetent and easily break down into reddish sand, proving that some of the extensive reddish sand that clogs the Jarilla Bolson comes from the Otero Escarpment as alluvium then is reworked by the wind.

The presence here of 138 cm of relatively fresh sediment that buries a well-developed soil defined by the 2Ab, 2Bkb and 2Bkmb horizons is evidence that this alluvial fan has been energy-reactivated in the Holocene, probably late Holocene. Reactivation possibly was linked to vertical movements along the Lee and Wilde faults to the east, with bolson downdropping commensurate with Sacramento Mountains/Otero Mesa uplifting.

4. *Pottery Site*. The Pottery site is a gully-cut sidewall exposure a few tens of meters west of the Benton Well-Sulphur Tank Road, about 0.5 km south of the Shorad-Benton Well Blacktop, and immediately north of the Old McGregor (Fleck's home) ranch (see Figure 15; A1 mapping unit, Orogrande N quad). The cut exposes four strata that are, from the top downwards, 25, 85, 70, and 80 cm thick. The gully sidewall was dressed down by backhoe, and both the dressed and natural exposures were utilized for the description. The full sediment-soil description is in Appendix D, a photo of the exposure is in Figure 60, chemical and particle size data are in Table 10, and graphs showing depth functions are in Figure 61. Figure 62 shows particle size expressed as percents for each of the four units. All units are pedogenized, Unit 3 more strongly than others. Land snails of the high spired dextral coiled *Physa virgata* kind occur in Units 2 and 3 (in the latter, 10 cm below its upper boundary) (snails identified by Professor Art Metcalf, Department of Biological Sciences, UTEP). Pottery sherds are present in some pedons of Unit 1, for which the site gets it name. In fact, pottery sherds are abundant all along the gully floor, presumably having eroded out of nearby and upstream sites. The geometry of the gully and certain bedform flow signatures indicate that flood waters episodically fill the channel, which debouches into nearby Benton Playa (see Figure 15). Benton Playa must therefore episodically hold water, perhaps significant amounts.

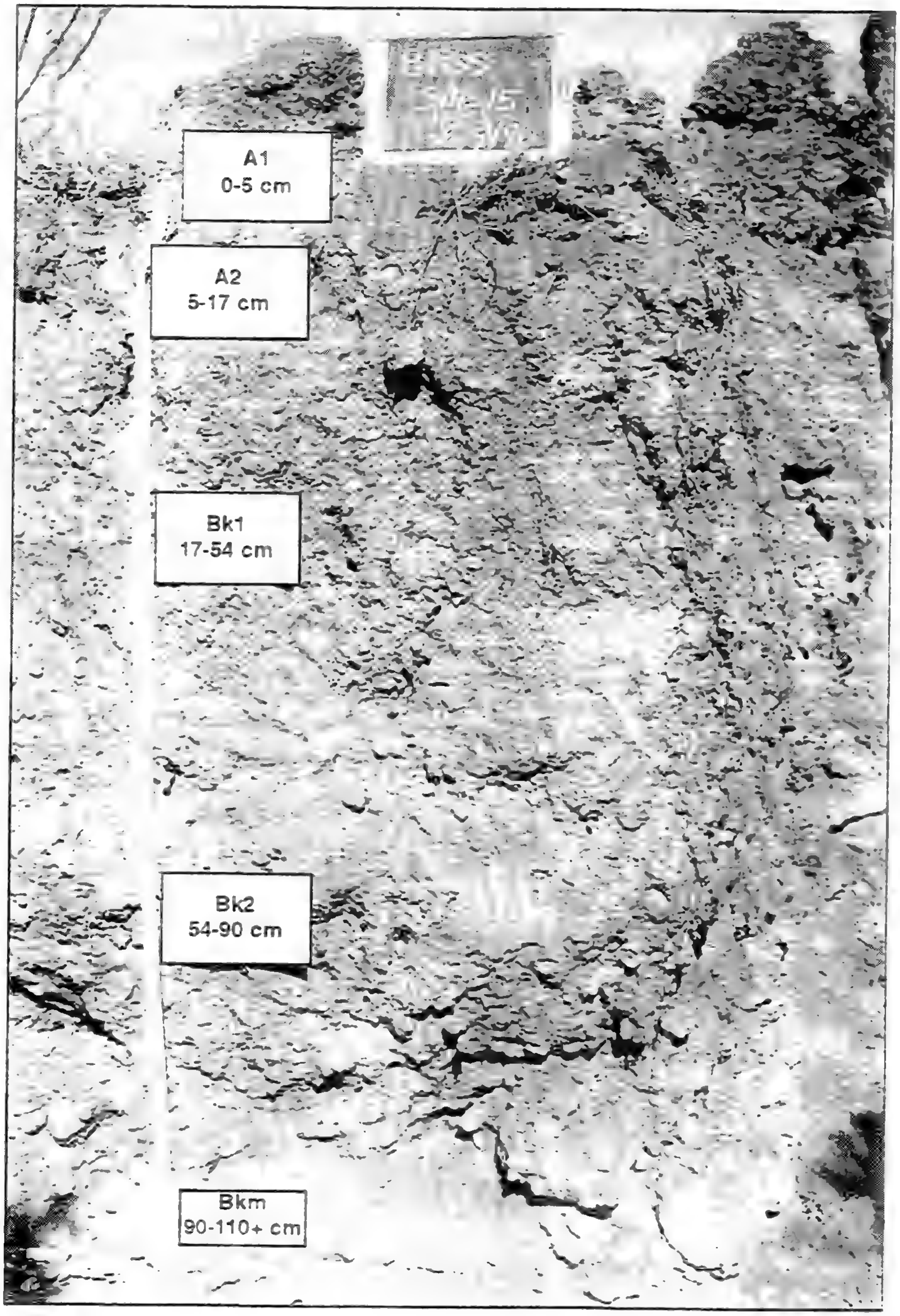


Figure 55 Cactus, site 15, soil horizons. The platy A1 horizon reflects recent sheetwash deposition. The reddish-pinkish tint of the largely destratified A2, Bk1, and Bk2 horizons typify colors on this fan, which derive from reddish Permian outcrops several km east and upslope. Surface badger mounds, one containing petrocalcic chunks, indicate bioturbation of the A2, Bk1, and Bk2 horizons and occasional penetration of the petrocalcic horizon (Bkm). Cicada-like burrows are subtle but abundant down to the Bk2 horizon, and clusters of rodent- and or rabbit-like fecal pellets occur in the A2, Bk1, and Bk2 horizons.

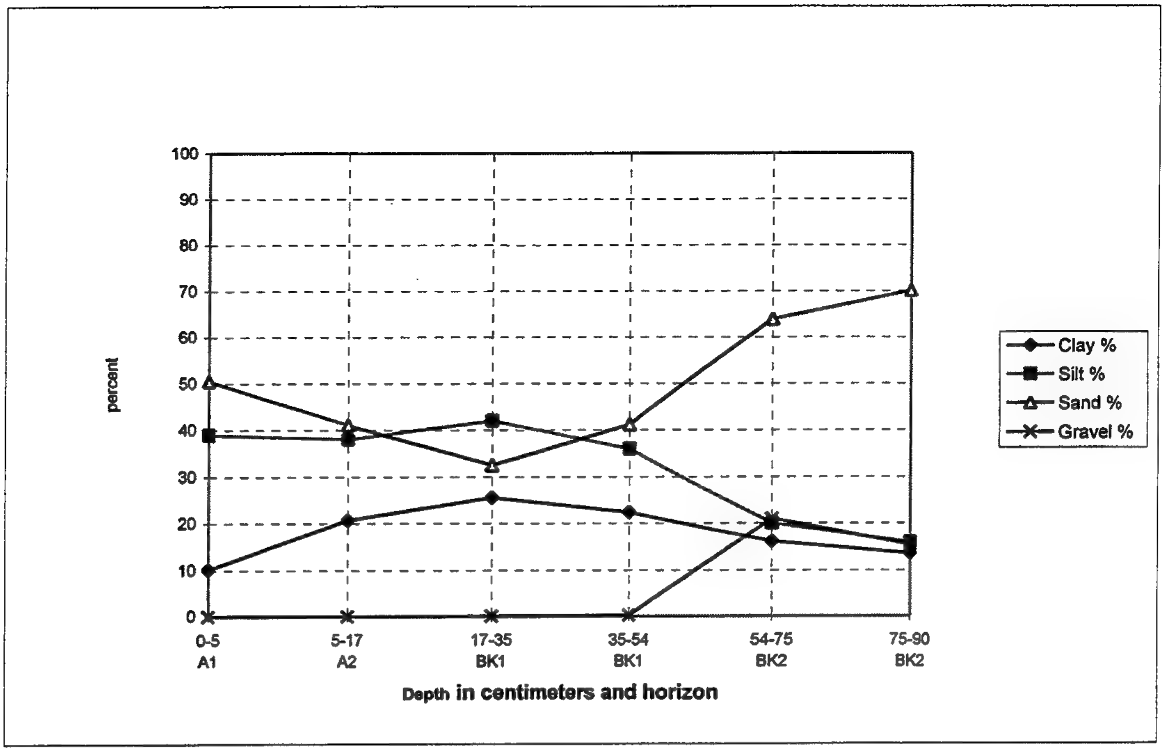
Table 8
Cactus, Site 15, McGregor Range, New Mexico
Particle Size and Chemical Data

Particle Size Data

Horizon	Depth	Sediment / Percent: Clay	Silt	Sand	Fine Silt	Coarse Silt	Very Fine Sand	Fine Sand	Medium Sand	Coarse Sand	Very Coarse Sand	Gravel	Textural Class
A1	0-5	10.20	39.00	50.50	17.10	22.30	29.90	17.50	0.60	0.70	1.80	0.00	L
A2	5-17	20.70	38.00	41.10	19.10	19.10	23.00	16.80	0.50	0.20	0.50	0.00	L
BK1	17-35	25.60	42.00	32.60	21.20	20.70	19.50	12.40	0.20	0.10	0.30	0.10	L
BK1	35-54	22.40	36.00	41.20	18.00	18.40	23.30	17.10	0.40	0.10	0.30	0.20	L
BK2	54-75	16.20	20.00	63.90	8.30	11.60	28.90	33.70	0.80	0.30	0.30	21.00	FSL
BK2	75-90	13.60	16.00	70.10	6.60	9.70	29.00	39.40	1.10	0.20	0.30	15.50	FSL

Chemical Data

Horizon	Depth	Ca meq/100g	Mg meq/100g	Na meq/100g	K meg/100g	Sum of Bases meq/100g	Acidity meq/100g	Al meq/ 100g	CEC by sum of cations meq/100g	CEC-7 (NH4OAc) meq/100g	CEC Bases + Al	Al Sat %	Base Sat by sum %	Base Sat by CEC-7 %	Organic Carbon %	Salt pH .01M CaCl2	Water pH
A1	0-5	41.70	2.00	0.10	0.90	44.70	0.00	--	44.70	12.20	--	--	100.00	100.00	0.70	7.40	7.90
A2	5-17	44.50	3.10	TR	1.10	48.70	0.00	--	48.70	13.80	--	--	100.00	100.00	0.70	7.50	8.00
BK1	17-35	43.80	3.50	0.10	0.90	48.30	0.00	--	48.30	11.70	--	--	100.00	100.00	0.40	7.50	7.90
BK1	35-54	46.50	4.00	0.10	0.70	51.30	0.00	--	51.30	10.70	--	--	100.00	100.00	0.40	7.50	8.00
BK2	54-75	43.00	4.40	0.20	0.60	48.20	0.00	--	48.20	9.20	--	--	100.00	100.00	0.30	7.50	8.00
BK2	75-90	41.60	6.60	0.50	0.40	49.10	0.00	--	49.10	8.20	--	--	100.00	100.00	0.40	7.50	7.80



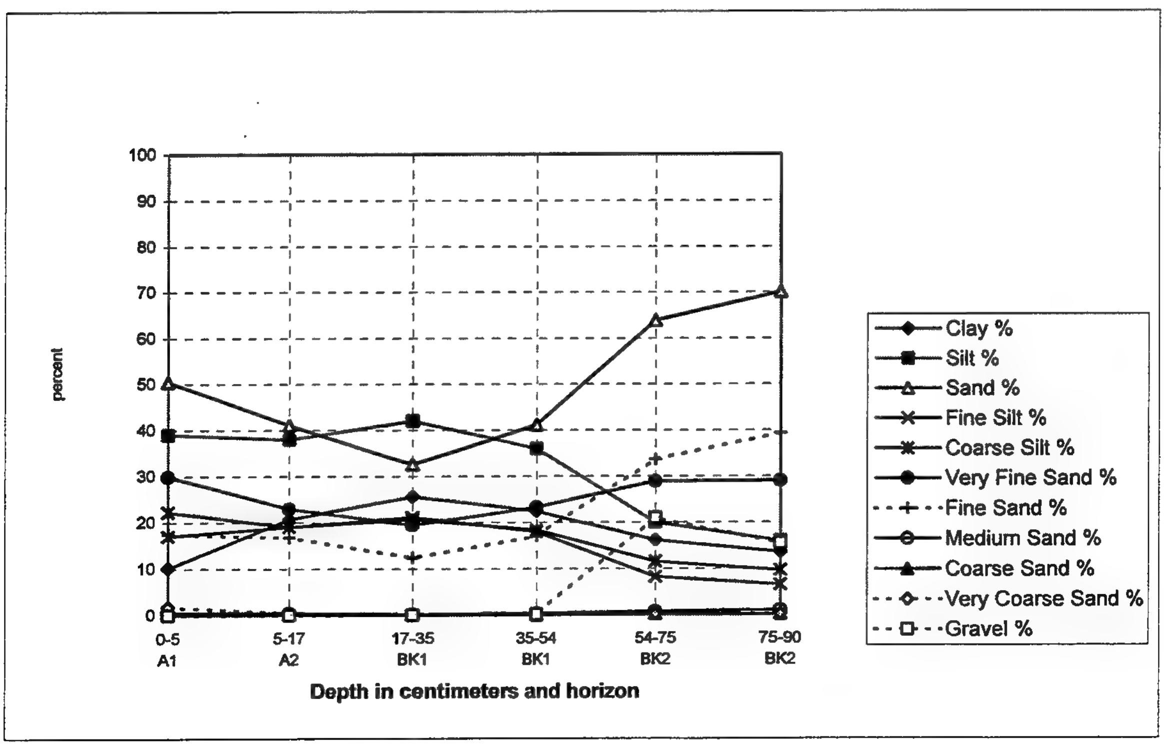


Figure 56. Cactus, site 15, depth functions of four (upper) and 11 (lower) particle sizes (data from Table 8).

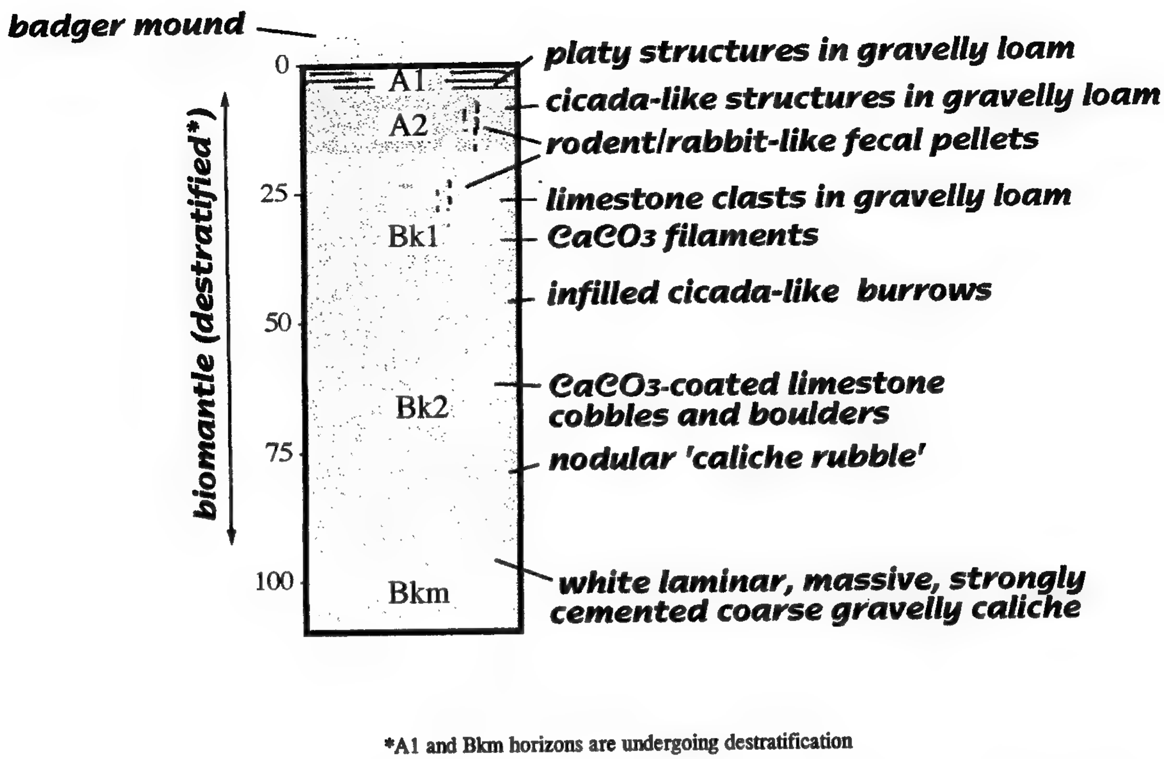


Figure 57. Profile schematic of described profile at Cactus, site 15, based on sediment-soil description (see Appendix D) and data from Table 8.

The backhoe-dressed portion of this profile shows little of the strongly expressed strata, structure, and side wall profile that the adjacent, naturally exposed stream bank displays. In pits and trenches that are long exposed to the elements, the subtleties and nuances of stratigraphy and soil evolution often are much better expressed.

The geomorphic significance of this section is that because each of the four alluvial units are clearly distinct, each bearing a different pedogenic identity, they were deposited separately, probably in four separate megafloods. They demonstrate that the Jarilla Bolson experiences major flood events from time to time, and that the periodic existence of playa lakes would have been attractive to humans and wildlife. This would explain the wide occurrence and abundance of prehistoric cultural materials in the Benton Playa area.

Tularosa Basin Zone

This zone encompasses the southwestern part of McGregor Range, mainly—though not exclusively—the portion of the basin underlain by ancient Rio Grande (Camp Rice) fluvial sediments that are veneered with historic-aged eolian Newman sands (sand sheets and sand piles). It also includes the toeslopes of fans that onlap the area along its eastern border. This zone is dominated by the La Mesa surface and the depressions and playas in it, and the near-ubiquitous blanket of historic Newman eolian cover sands.

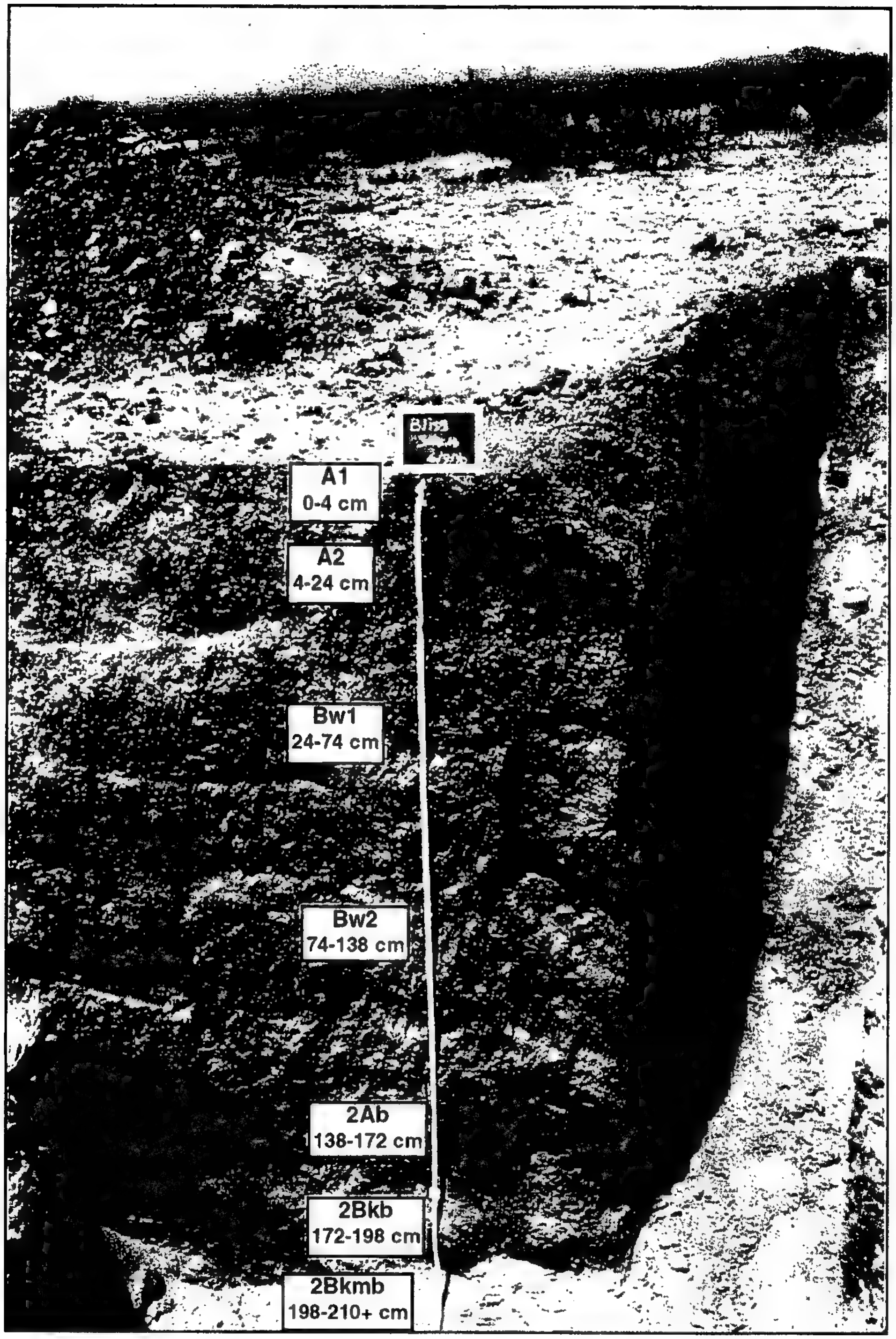


Figure 58. Permian Sandstone/Limestone, site 16, stratigraphy. The site is on the upper toeslopes of an alluvial fan that heads on the Otero Escarpment to the east. The gravels in the A2 horizon and below consist of both redbed sandstone and grayish limestones derived from Permian rocks along the Escarpment. The reddish sandstone clasts are friable and easily break down into reddish sand, proving that some of the sand that clogs the Jarilla Bolson is from Permian rocks, at least in this part of the Tularosa Basin. That relatively fresh sediment buries a well-developed soil is evidence that the fan has been dynamically reactivated, probably in the late Holocene. Reactivation may have been linked to vertical movements along the Otero Escarpment Fault, west side down.

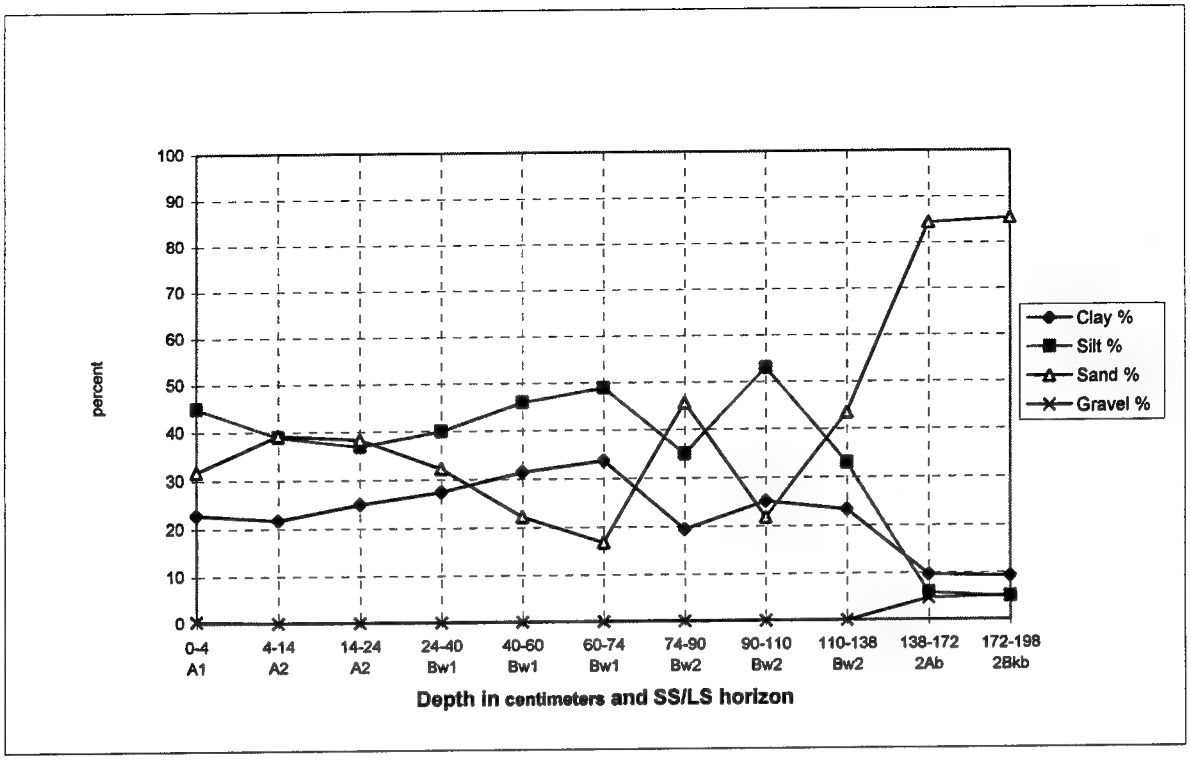
Table 9
Permian SS/LS, Site 16, McGregor Range, New Mexico
Particle Size and Chemical Data

Particle Size Data

		Sediment / Percent											
Horizon	Depth	Clay	Silt	Sand	Fine Silt	Coarse Silt	Very Fine Sand	Fine Sand	Medium Sand	Coarse Sand	Very Coarse Sand	Gravel	Textural Class
A1	0-4	22.90	45.00	31.80	25.00	20.40	20.70	10.60	0.10	0.10	0.20	0.40	L
A2	4-14	21.80	39.00	39.30	22.40	16.50	23.50	14.20	0.50	0.30	0.90	0.00	L
A2	14-24	25.10	37.00	38.40	19.20	17.40	23.00	14.20	0.30	0.20	0.60	0.00	L
Bw1	24-40	27.50	40.00	32.30	21.60	18.60	21.10	10.60	0.20	0.10	0.20	0.00	CL
Bw1	40-60	31.50	46.00	22.30	26.80	19.30	15.00	6.90	0.10	0.10	0.20	0.00	CL
Bw1	60-74	33.80	49.00	16.90	29.90	19.40	11.40	4.60	0.20	0.50	0.20	0.00	SICL
Bw2	74-90	19.50	35.00	45.70	12.70	22.10	35.40	10.00	0.00	0.10	0.10	0.00	L
Bw2	90-110	25.20	53.00	21.90	22.60	30.20	18.30	3.60	0.00	0.00	0.00	0.00	SIL
Bw2	110-138	23.40	33.00	43.50	19.30	13.80	26.80	16.30	0.20	0.10	0.10	0.00	L
2Ab	138-172	9.70	5.90	84.40	1.60	4.30	25.90	56.20	1.60	0.70	0.10	4.70	LFS
2Bkb	172-198	9.40	5.00	85.50	2.40	2.70	24.70	58.80	1.30	0.70	0.10	5.30	LFS
2Bkmb petrocalcic	198+												

Chemical Data

Horizon	Depth	Ca meq/100g	Mg meq/100g	Na meq/100g	K meq/100g	Sum of Bases meq/100g	Acidity meq/100g	Al meq/100g	CEC by sum of cations meq/100g	CEC-7 (NH4OAc) meq/100g	CEC Bases + Al	Al Sat %	Base Sat by sum %	Base Sat by CEC-7 %	Organic Carbon %	Salt pH .01M CaCl2	Water pH
A1	0-4	43.00	2.10	0.10	1.40	46.60	0.00	--	46.60	17.50	--	--	100.00	100.00	1.10	7.50	8.00
A2	4-14	49.20	2.90	TR	1.50	53.60	0.00	--	53.60	15.80	--	--	100.00	100.00	0.80	7.50	8.00
A2	14-24	49.20	2.90	TR	1.30	53.40	0.00	--	53.40	13.80	--	--	100.00	100.00	0.60	7.50	7.80
Bw1	24-40	49.60	2.90	TR	0.90	53.40	0.00	--	53.40	12.90	--	--	100.00	100.00	0.50	7.50	7.90
Bw1	40-60	48.70	3.60	0.10	0.70	53.10	0.00	--	53.10	13.40	--	--	100.00	100.00	0.40	7.50	7.90
Bw1	60-74	50.50	4.60	0.20	0.60	55.90	0.00	--	55.90	13.90	--	--	100.00	100.00	0.50	7.50	7.80
Bw2	74-90	47.10	4.10	0.10	0.30	51.60	0.00	--	51.60	10.00	--	--	100.00	100.00	0.20	7.50	7.80
Bw2	90-110	45.50	5.70	0.10	0.40	51.70	0.00	--	51.70	12.10	--	--	100.00	100.00	0.20	7.50	7.80
Bw2	110-138	46.30	5.80	0.10	0.30	52.50	0.00	--	52.50	11.30	--	--	100.00	100.00	0.20	7.50	7.90
2Ab	138-172	41.40	4.10	0.10	0.20	45.80	0.00	--	45.80	6.40	--	--	100.00	100.00	0.10	7.50	8.00
2Bkb	172-198	41.80	4.10	0.10	0.20	46.20	0.00	--	46.20	6.10	--	--	100.00	100.00	0.10	7.50	8.00
2Bkmb petrocalcic	198+																



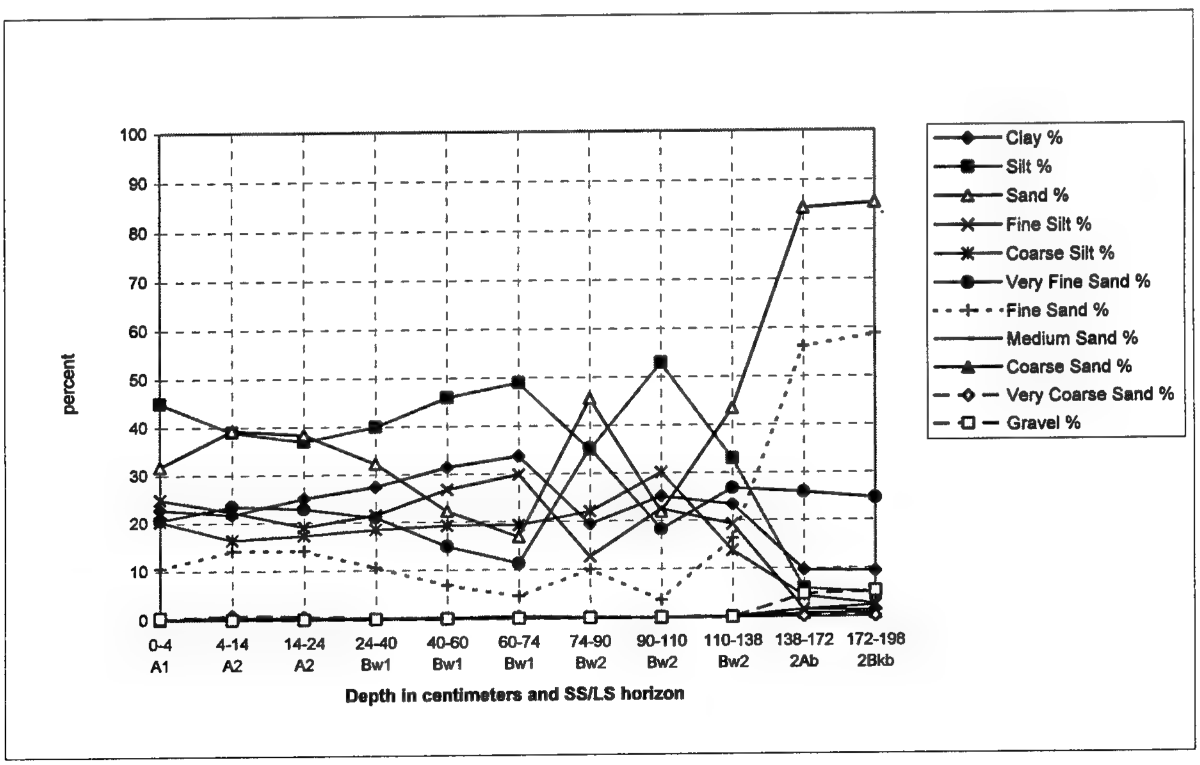


Figure 59. Permian Sandstone/Limestone, site 16, depth functions of four (upper) and 11 (lower) particle sizes (data from Table 9).

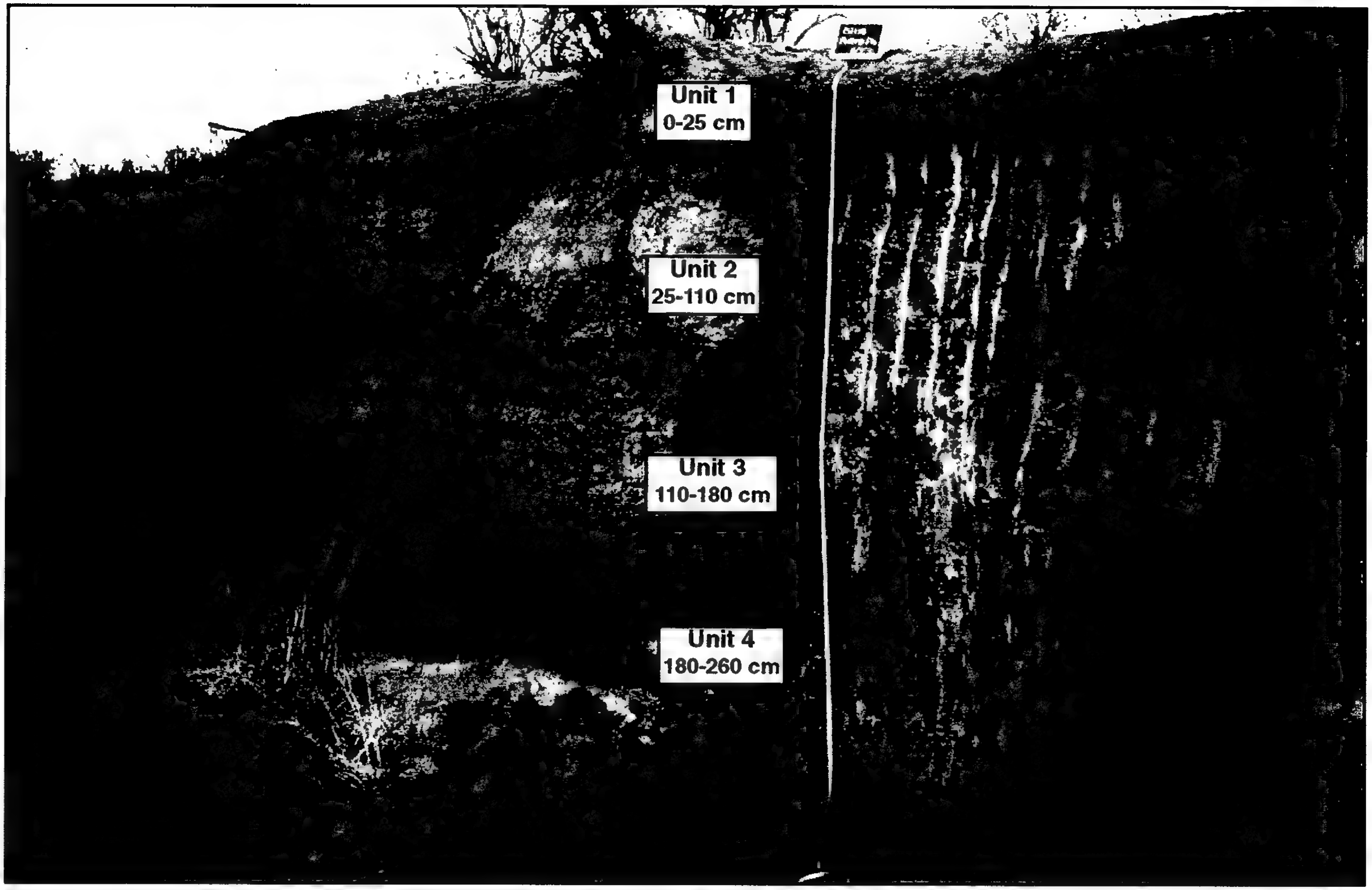


Figure 60. Pottery, site 1, soil profile. Distal toeslope sediments from coalesced alluvial fans that drain from the Otero Escarpment and the Northwest Bedrock Hueco Finger. This pedogenicized, largely destratified sediment stack is calcareous throughout. The upper part of Unit 1 contains pottery sherds, which are erosionally exposed across its surface.

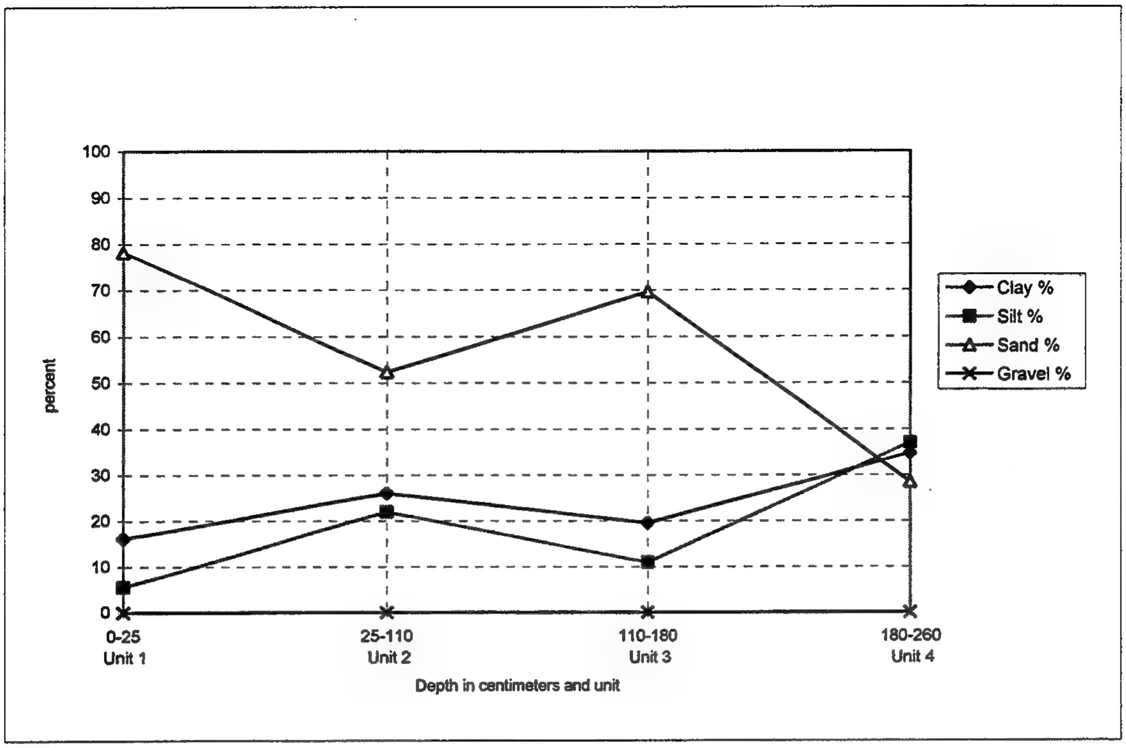
Table 10
Pottery, Site 1, McGregor Range, New Mexico
Particle Size and Chemical Data

Particle Size Data

Horizon	Depth	Sediment / Percent: Clay	Silt	Sand	Fine Silt	Coarse Silt	Very Fine Sand	Fine Sand	Medium Sand	Coarse Sand	Very Coarse Sand	Gravel	Textural Class
Unit 1	0-25	16.20	5.60	78.20	5.10	0.50	9.20	61.30	6.50	1.10	0.00	0.00	FSL
Unit 2	25-110	26.00	22.00	52.40	18.00	3.60	17.50	33.80	0.90	0.20	0.00	0.00	SCL
Unit 3	110-180	19.60	11.00	69.70	6.50	4.20	24.00	43.40	1.70	0.60	0.00	0.00	FSL
Unit 4	180-260	34.70	37.00	28.50	30.10	6.70	11.90	14.70	1.10	0.70	0.00	0.00	CL

Chemical Data

Horizon	Depth	Ca meq/100g	Mg meq/100g	Na meq/100g	K meg/100g	Sum of Bases meq/100g	Acidity meq/100g	Al meq/ 100g	CEC by sum of cations meq/100g	CEC-7 (NH4OAc) meq/100g	CEC Bases + Al	Al Sat %	Base Sat by sum %	Base Sat by CEC-7 %	Organic Carbon %	Salt pH .01M CaCl2	Water pH
Unit 1	0-25	41.80	2.80	0.10	0.80	45.50	0.00	–	45.50	9.30	–	–	100.00	100.00	0.20	7.40	7.90
Unit 2	25-110	44.20	3.60	0.50	0.90	49.20	0.00	–	49.20	17.10	–	–	100.00	100.00	0.20	7.40	7.70
Unit 3	110-180	44.30	3.20	0.30	0.60	48.40	0.00	–	48.40	11.30	–	–	100.00	100.00	0.20	7.40	7.80
Unit 4	180-260	49.70	5.10	0.50	1.00	56.30	0.00	–	56.30	18.90	–	–	100.00	100.00	0.30	7.40	7.50



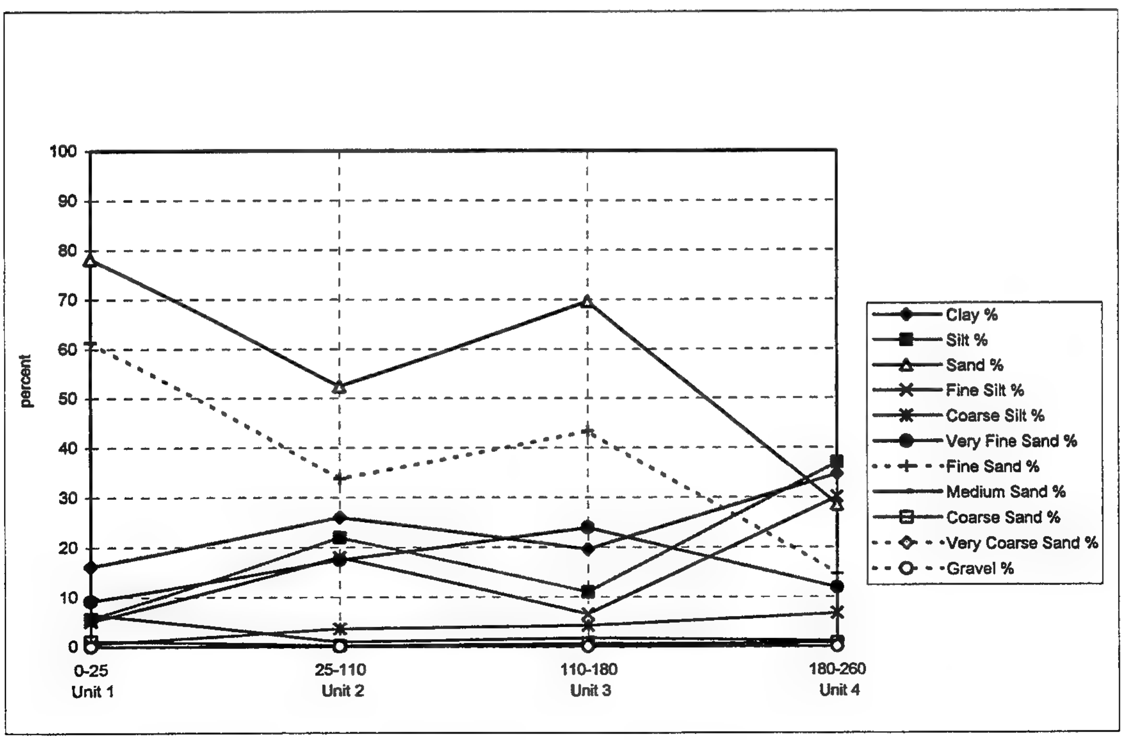


Figure 61. Pottery, site 1, depth functions of four (upper) and 11 (lower) particle sizes (no gravels are present; data from Table 10).

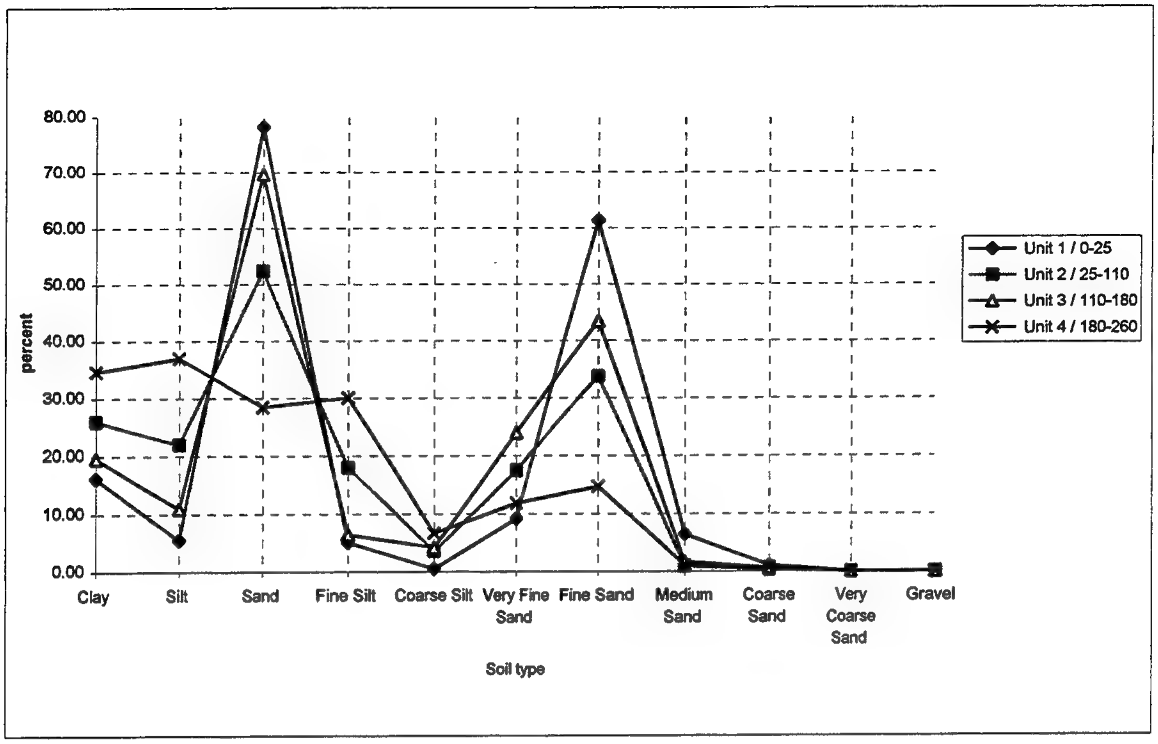


Figure 62. Particle size expressed as percents for each of the four units that are exposed at Pottery, site 1 (data from Table 10).

La Mesa Surface: Faults, Camp Rice Sediments, La Mesa Surface (Doña Ana Soils), Dune Sheets, and Depressions and Playas

1. *Faults*. A series of en echelon normal faults in the far southwestern part of McGregor in the Newman area has generated considerable local relief. The risers and steps that travelers on Highway 54 experience between Newman and McGregor Base Camp Road are manifestations of these faults, offsets of which can be seen on the bed of the diagonal road that runs between Newman and McGregor Range Camp (Figure 63).

Hot Well Fault, a locally significant expression of this tectonic activity, runs from Hot Wells southeast of Meyer Small Arms Range towards the northwest (immediately south of McGregor Range Camp), then cuts across the McGregor Entrance Blacktop at Missile Gate, then trends west-northwest into the Doña Ana Range (mapped on Newman quad). Certain depressions south, southwest, and west of McGregor Range Camp are linked to this fault.

Lake Tank and Three Buttes faults, both of which generally strike north-south, more or less mark the boundary between the Tularosa Basin and Broken Escarpment-Hueco Mountains zones in this part of McGregor Range (Desert and Desert SE quads). These two faults have produced some of the major depressions and playas in the basinal part of the base, for example Lake Tank, Faultline, and Snail playas, plus other playas around and northwest of Three Buttes, all of which periodically contain lakes (see Figure 28; Desert and Desert SE quads). It may be that most of the playas in the basinal part of McGregor are, in the first instance, fault related (deflation and leak-through processes are, of course, contributory).

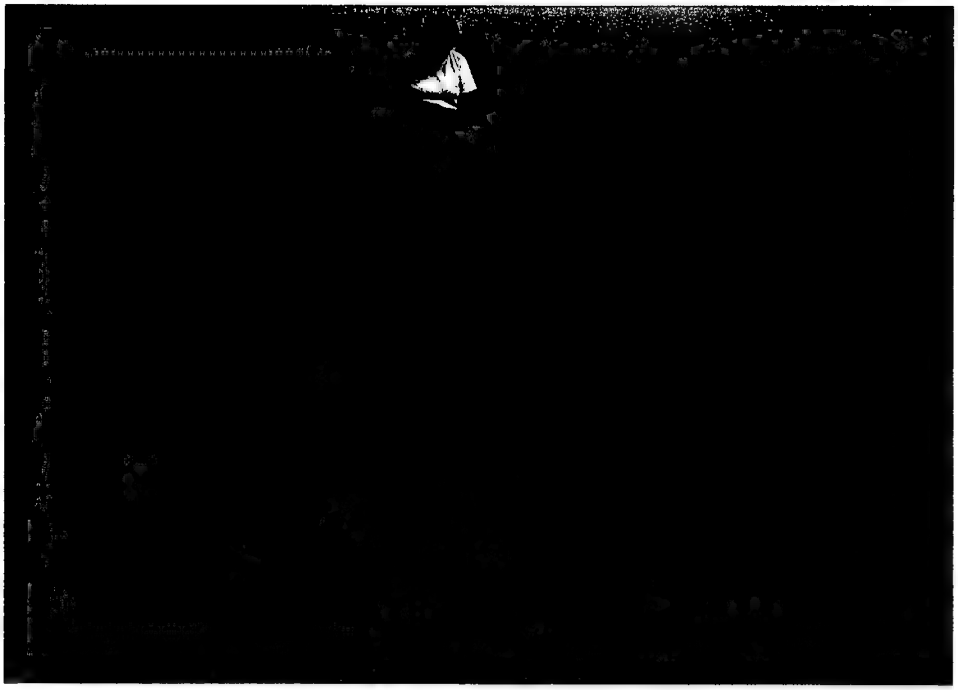


Figure 63. Faulted petrocalcic horizon immediately in front of, and parallel with, the fault scarp along Meyer Range Road about 1.5 km northeast of Newman on McGregor Range, New Mexico. Top photo shows assistant D. N. Johnson pointing to fault-ruptured caliche on the surface cutting diagonally (NW to SE) across Meyer Range Road. The fault has 'caliche fault gouge' associated with it. Bottom photo, Camp Rice Formation fluvial gravels at the base of fault scarp along Meyer Range Road about 1.5 km northeast of Newman on the McGregor Range, NM. The exotic pumice was deposited more than 700,000 years ago by the ancestral Rio Grande, which then flowed into this part of the Tularosa Basin through Anthony Pass. See Figure 64 for a close-up of these and other Camp Rice fluvial facies clasts.

2. *Camp Rice Fluvial Sediments.* As indicated, the La Mesa surface is underlain by river-deposited Camp Rice gravels and sands of Pleistocene age. They are believed by some (e.g., Hawley 1975a; Monger 1993a) to have been deposited by the ancestral Rio Grande when it flowed through Fillmore Pass between the Organ and Franklin mountains (see Figure 2) and meandered across the southern part of the Tularosa Basin, as far north as the Jarilla Mountains (see Figures 19 and 20). The Camp Rice sediments contain volcaniclastic pebbles, presumably from the Jemez volcanic region north of Albuquerque, that are similar to those still carried by the modern Rio Grande. Figures 63 and 64 show examples of Camp Rice volcaniclastic fluvial gravels that were collected in the Chaparral Sand and Gravel Pit at Newman, along the Newman-to-McGregor Range Camp-Road 1.5 km northeast of Newman, and from Borrow Pit 1 at the Missile Gate entrance to McGregor.

3. *La Mesa Surface and Doña Ana Soils, Newman Sand and Bluepoint-Pintura Soils.* The basinal part of McGregor is principally underlain by the La Mesa surface that has been described regionally by various researchers (Derr 1981; Gile and Hawley 1981; Hawley 1975a; Hawley and Kottlowski 1969; Monger 1993). The surface is dominated by Doña Ana soils (Typic Haplargids) formed in Camp Rice fluvial sediments, and Pintura and Bluepoint soils (Typic Torripsamments) formed in coppice dunes and sand sheets. The coppice dunes and sand sheets—the 'Newman sands' of Pigott (1977)—often bury the La Mesa surface and the Doña Ana soils.

Exposures of Doña Ana-like soils developed in Camp Rice sediments are in Borrow Pits 1, 2, and 3 along the north side of the McGregor Entrance Blacktop, and in several borrow pits along Meyer Range Road (e.g., La Mesa Borrow Pit; all are located on Desert SW quad, mapping unit DSC/CR/Pl). Borrow Pits 1-3 were backhoe-dressed for general observation and photographic purposes. A general soil description of the Doña Ana soil is given in Appendix C, and Figures 65-68 give different views of this soil in various exposure and landscape contexts.

4. *La Mesa Depressions, Playa Sediments, and Soils.* Many depressions with playas occur on the La Mesa surface (see Figure 25). All lie within the Bolson Floor Complex mapping unit. The following five were examined via backhoe pits in this study: Meyer Range Road depression, Range Control depression, Alvarado Tank No. 2, Vertisol Playa, and Gypsum Playa.

Meyer Range Road Depression, site 47, is on the south side of the road in the depression 5.2 km west of Meyer Small Arms Range, and appears to be a porous leak-through type playa (Desert SW quad, mapping unit Pl). An abbreviated sediment-soil description is in Appendix D, Figure 69 is a photograph of the described profile, and Figure 70 is a profile schematic. The depression floor has Camp Rice fluvial gravels and sand exposed at the surface and the upper part of the soil profile is developed in these gravelly sands. A lithologic discontinuity occurs at 2.2 m depth, below which occurs Camp Rice lake clays. The depressional floor is thus characterized as consisting of some 2 m of Camp Rice gravelly sands over an undetermined thickness of Camp Rice lake beds.

Range Control Depression, site 50, lies within the Bolson Floor Complex and is 2.3 miles (3.7 km) north-northwest of Borrow Pit 1 and the McGregor Missile Gate (Desert SW quad, mapping unit Pl). A full sediment-soil description is in Appendix D, the character of the described and nearby pedons is shown in Figure 71, and Figure 72 is a profile schematic. This soil formed in a thin sheet sand in a La Mesa depression within which, and on the surface of which, water-polished Camp Rice gravels are occasionally met, presumably brought up into and dispersed throughout the sand sheet by bioturbation. No playa-type sediments are present at the described site, and this may be another leak-through type depression/playa.

Alvarado Tank No. 2, site 39, is about 60 m south of Avarado Tank No. 2 on the Desert NE quad (mapping unit A1; see also Figure 29). This more or less playa actually occupies the very distal toeslope of an alluvial fan complex that heads to the southeast, east, northeast, and north. Several playas are nearby (see Figure 29), and, when major storms or wet periods occur, the playas coalesce and this area becomes a large lake,

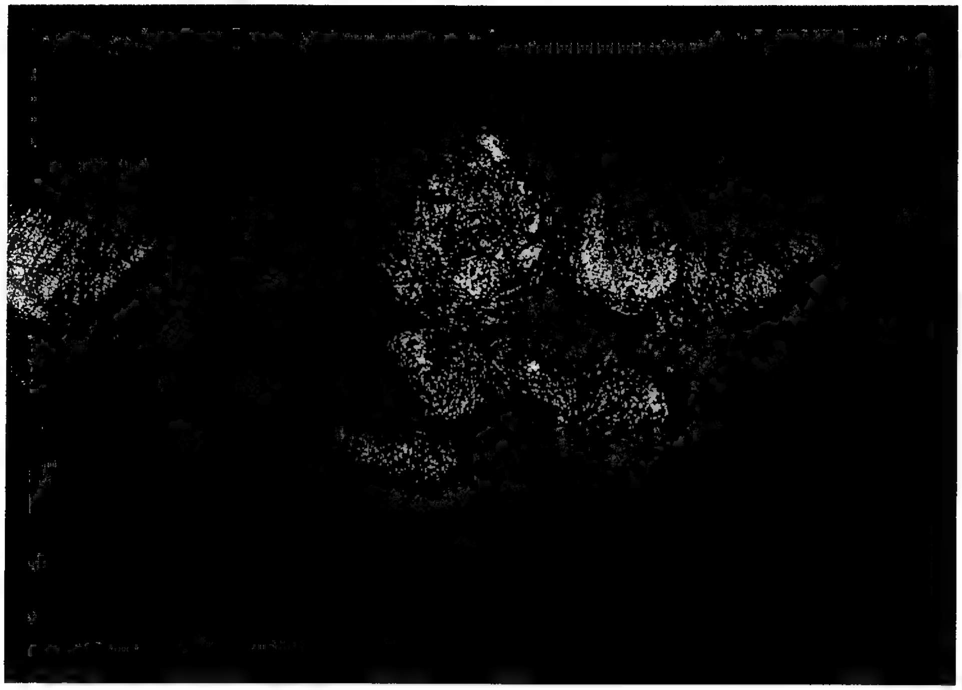


Figure 64. Camp Rice Formation fluvial gravels. Top photo shows 14 exotic volcaniclastic rocks. Two of the black obsidian pebbles and the large pumice pebble are from Chaparral Sand and Gravel pit immediately west of Hwy 54 just north of Newman. The eight small pumice pebbles are from the pumice-rich alluvial gravel bar in Camp Rice fluvial sediments shown in Figure 63. The dark vesicular basalt pebble (far right) and all the Camp Rice gravels in the lower photo are from Borrow Pit 1 along the McGregor Entrance Blacktop just west of, and near, the missile monument gate at McGregor Base Camp, McGregor Range, New Mexico.

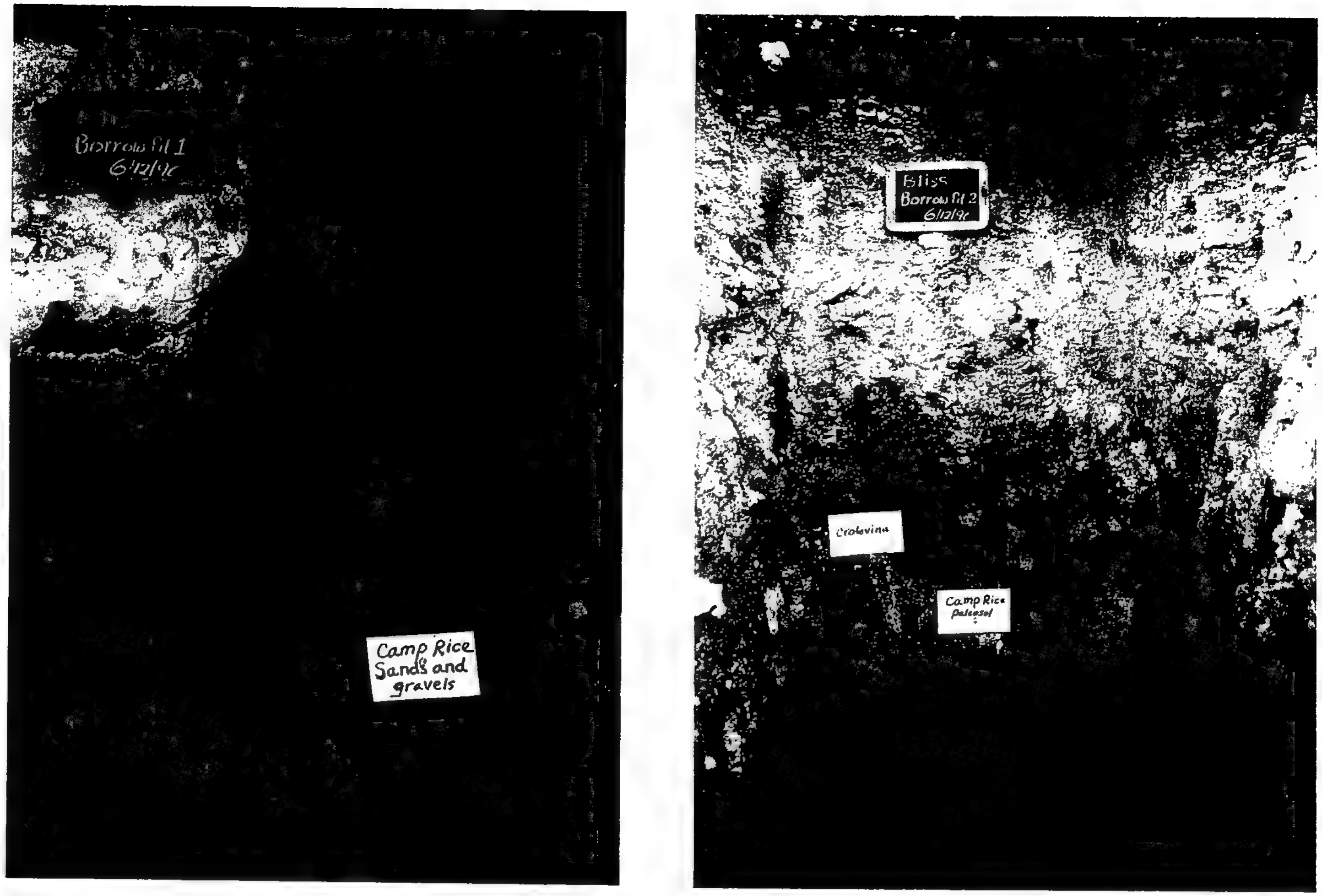


Figure 65. Borrow Pits 1 and 2, showing exposures of Doña Ana-like soils developed in Camp Rice sediments. Left photo: Borrow Pit 1, in depression of La Mesa surface produced by Hot Well Fault, north side of McGregor Entrance Blacktop just west of missile gate entrance to McGregor Range Camp. The Doña Ana-like soil formed in mid-Pleistocene Camp Rice gravelly sandy alluvial sediments. The interrupted, displaced, and disturbed petrocalcic horizon segments and associated large and small calcified krotovina infillings in surrounding loamy sand soil are intermittent in this depressional soil and apparently reflect long-term bioturbation and possibly fault-related movements. The lack of recent playa sediments (silts and clays) evident in this part of the depression suggests deflation and/or solutional and suspended sediment leakage of surface runoff into subsurface Camp Rice aquifers. Right photo: Borrow Pit 2, located on north side of McGregor Entrance Blacktop between Borrow Pits 1 and 3 at juncture with road that heads north. Soil formed in mid-Pleistocene Camp Rice fluvial sediments. In the pedons exposed in this backhoe trench, unlike those in the Borrow Pit 1 trench, the calcic horizonation vector has predominated over the bioturbation vector. Even so, the caliche blebs below the laminar petrocalcic horizon are largely krotovina-nucleated, with relatively recent uncalcified krotovinas also present.

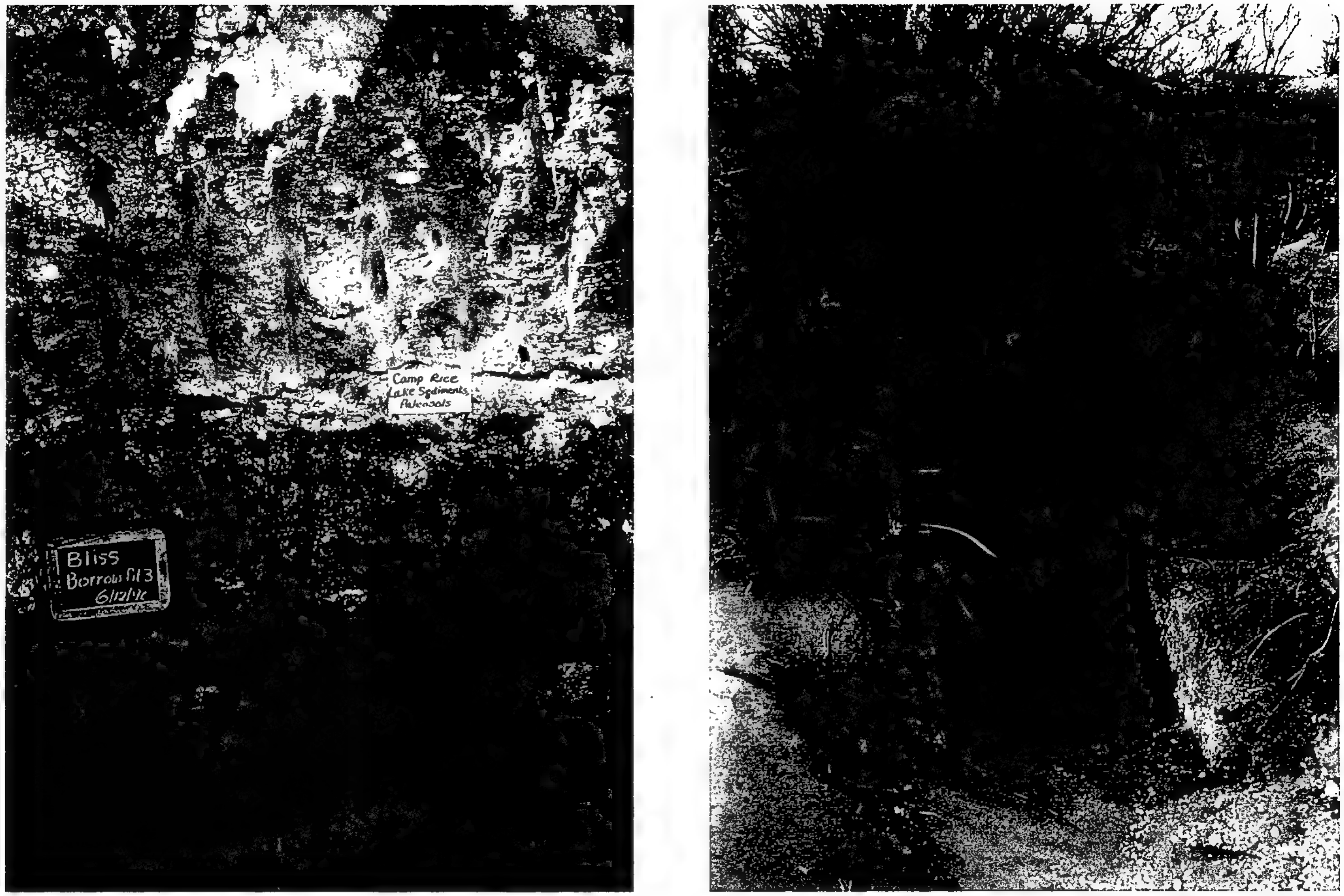


Figure 66. Photos of Borrow Pits 3 and 1. Left photo, Borrow Pit 3, north side of McGregor Entrance Blacktop about 2 km east of Highway 54, west of Borrow Pit 2. Soil is formed in mid-Pleistocene Camp Rice lake sediment. The layer on which the chalkboard is affixed is a vertisol with a calcic horizon. The vertisol formed in lake sediment prior to Pleistocene accretion of thin sand which buried it, and into which a Doña Ana-like soil then formed. Right photo: a trenched, mesquite-anchored coppice dune at Borrow Pit 1 along the north side of the McGregor Entrance Blacktop, which shows a minimal Pintura soil formed in it. Although some destratification has occurred, mainly by root growth, the dune is still largely stratified and very recent, and probably is still forming.

Figure 67. Two views of La Mesa Borrow Pit, Meyer Range Road (Desert SW quad). Upper photo shows platy, laminar upper petrocalcic horizon. Bottom photo shows a closeup of a calichefied infilled cicada burrow that is beginning to break up via biomechanical activity. Note other calichefied infilled cicada burrow segments that were once contiguous, but now dispersed.

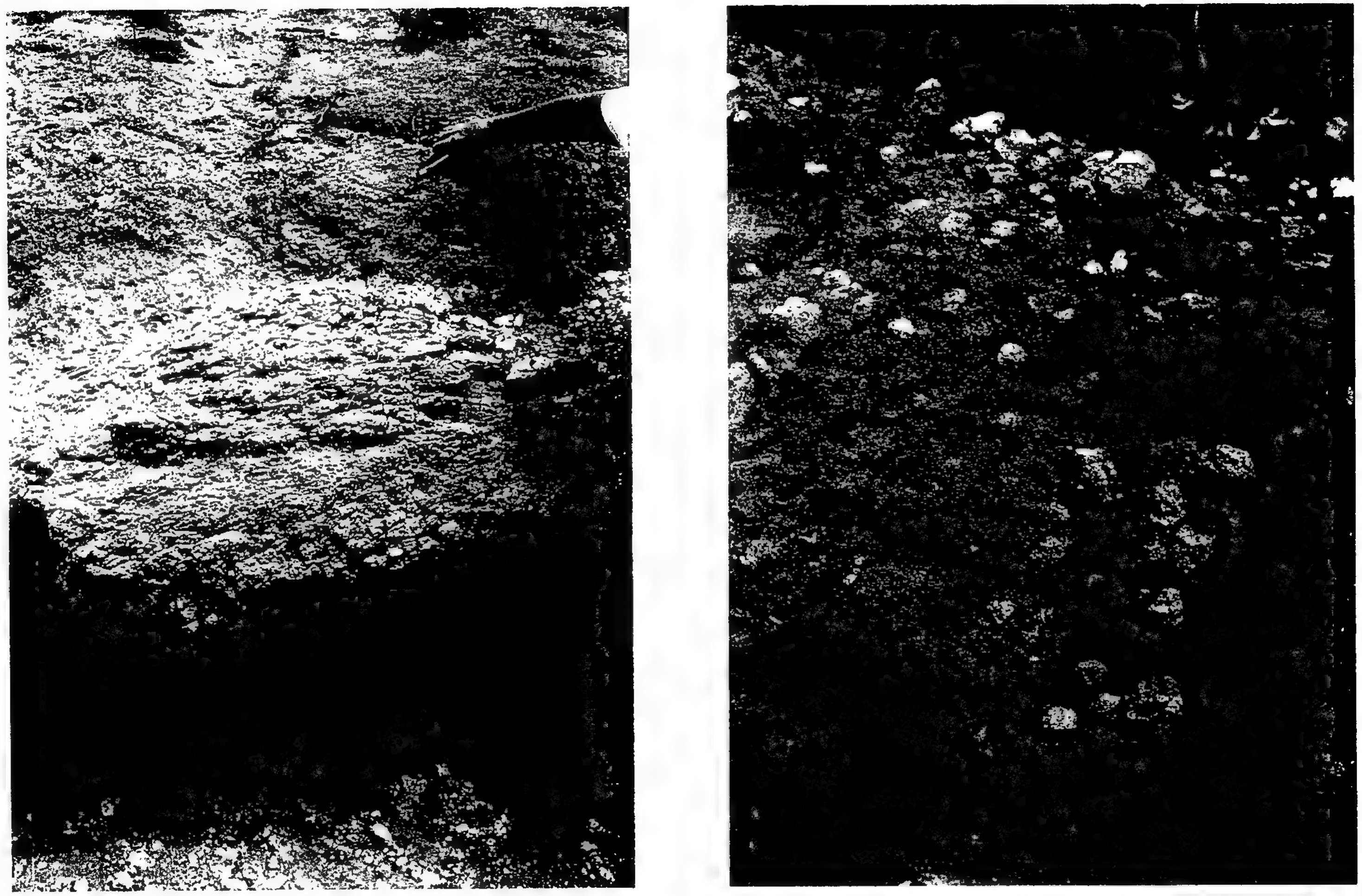


Figure 68. Photos of La Mesa Borrow Pit, Meyer Range Road (Desert SW quad). Two views of the La Mesa surface Doña Ana-like soil. Left photo shows the top of the pre-borrow pit soil (at top of hand) where most calichefied cicada burrow infilling segments end. Note concentration of calichefied cicada burrow segments along top of petrocalcic horizon. The concentration of segments may be due to long-term cicada burrowing, where segments are gradually lowered by within-soil bioturbation. Upper surface of petrocalcic horizon is gradually built up by segments added in this way, which then become cemented. Right photo shows that calichefied cicada burrow segments are dispersed throughout topsoil.

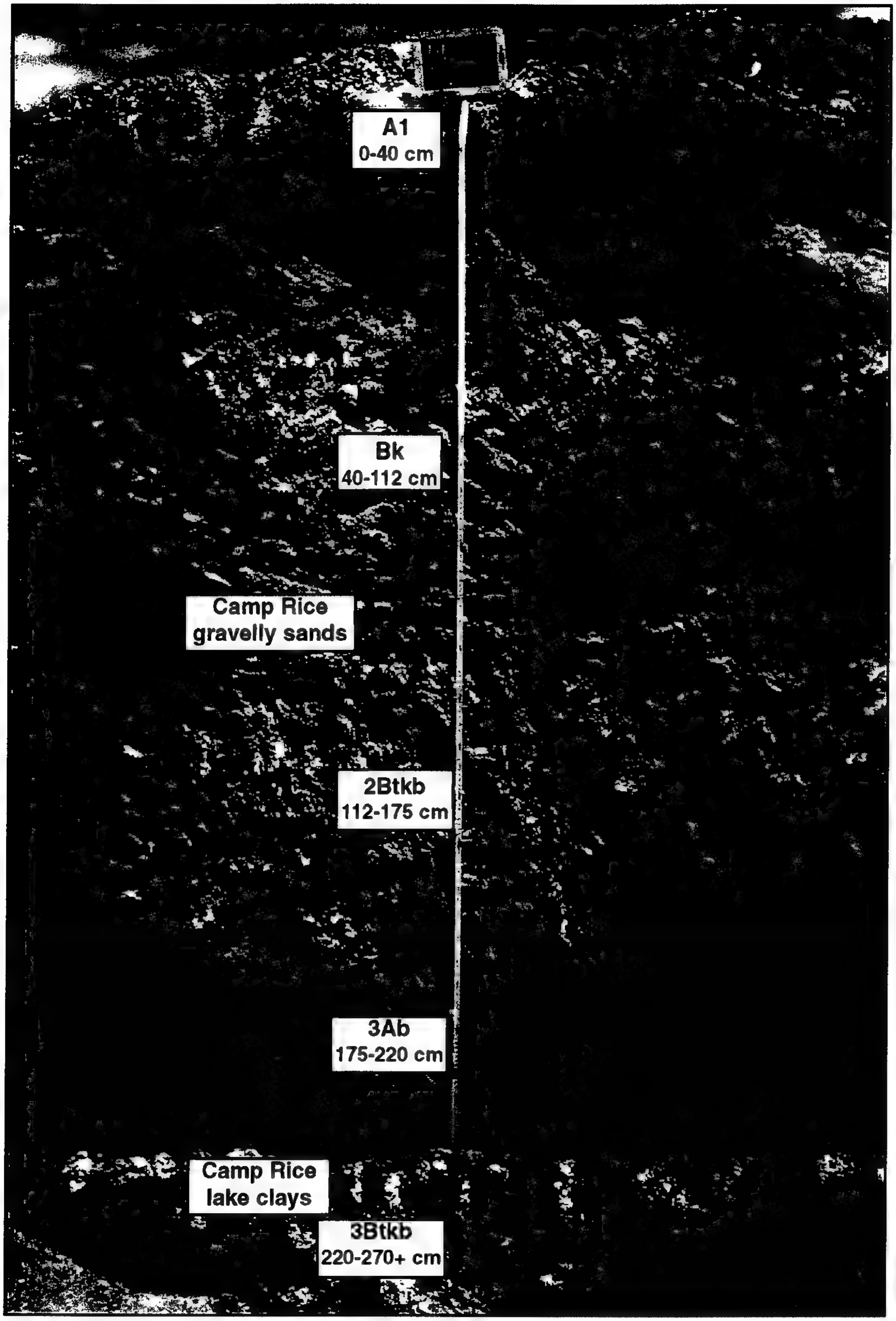
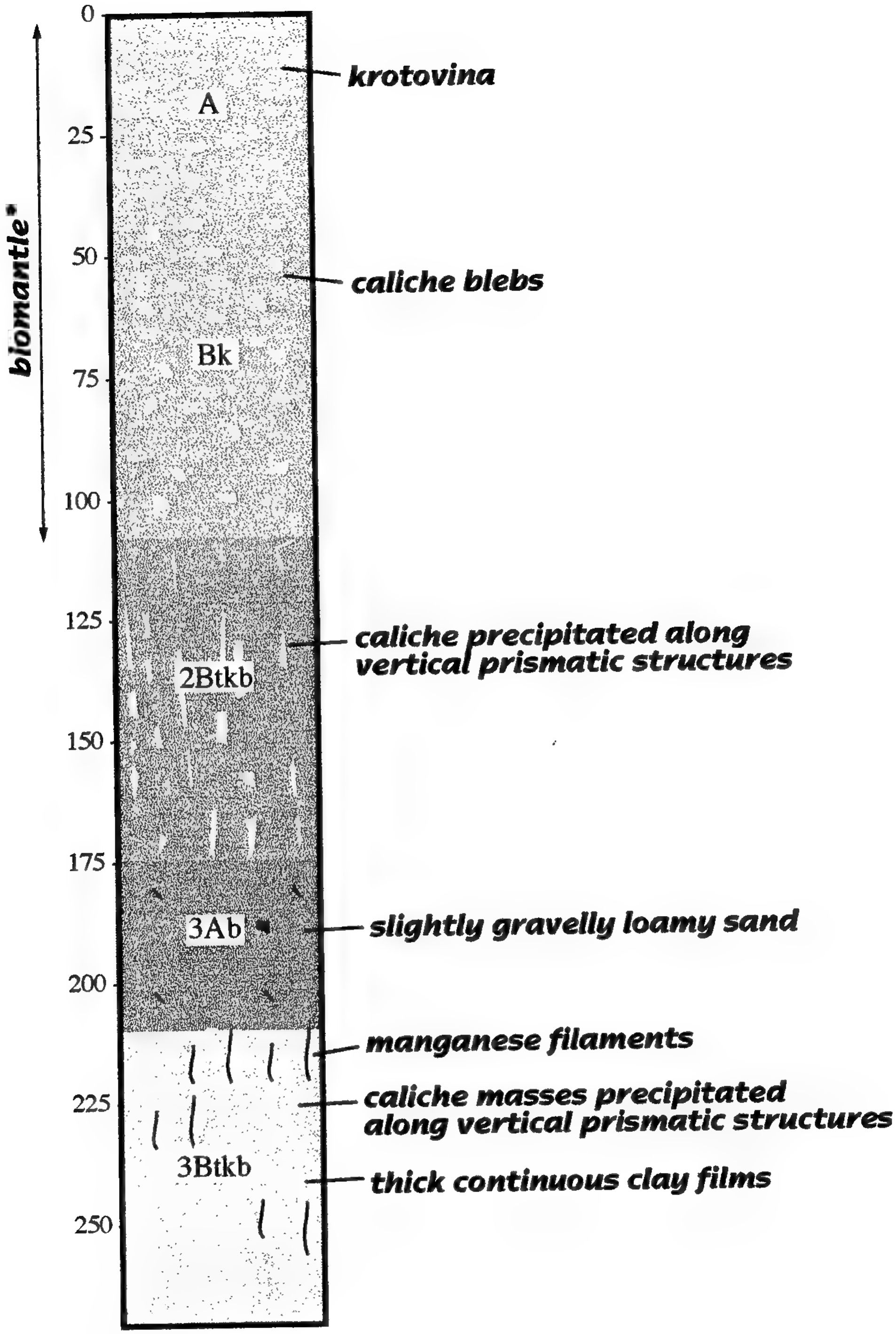


Figure 69. Meyer Range Road Depression, site 47, stratigraphy. The stratigraphy here is Camp Rice gravelly sands above Camp Rice lake clays, all of which have been pedogenicized to varying degrees. Krotovina occur from the surface to 112 cm depth, with animal and branchiated root systems abundant.



*During the soil forming processes, bioturbation is occurring in all soils. The paleosols had biomantles too (evidence for these paleobiomantles is often erased by organizing vectors occurring through time).

Figure 70. Profile schematic of site 47, Meyer Range Road Depression, McGregor Range, New Mexico.

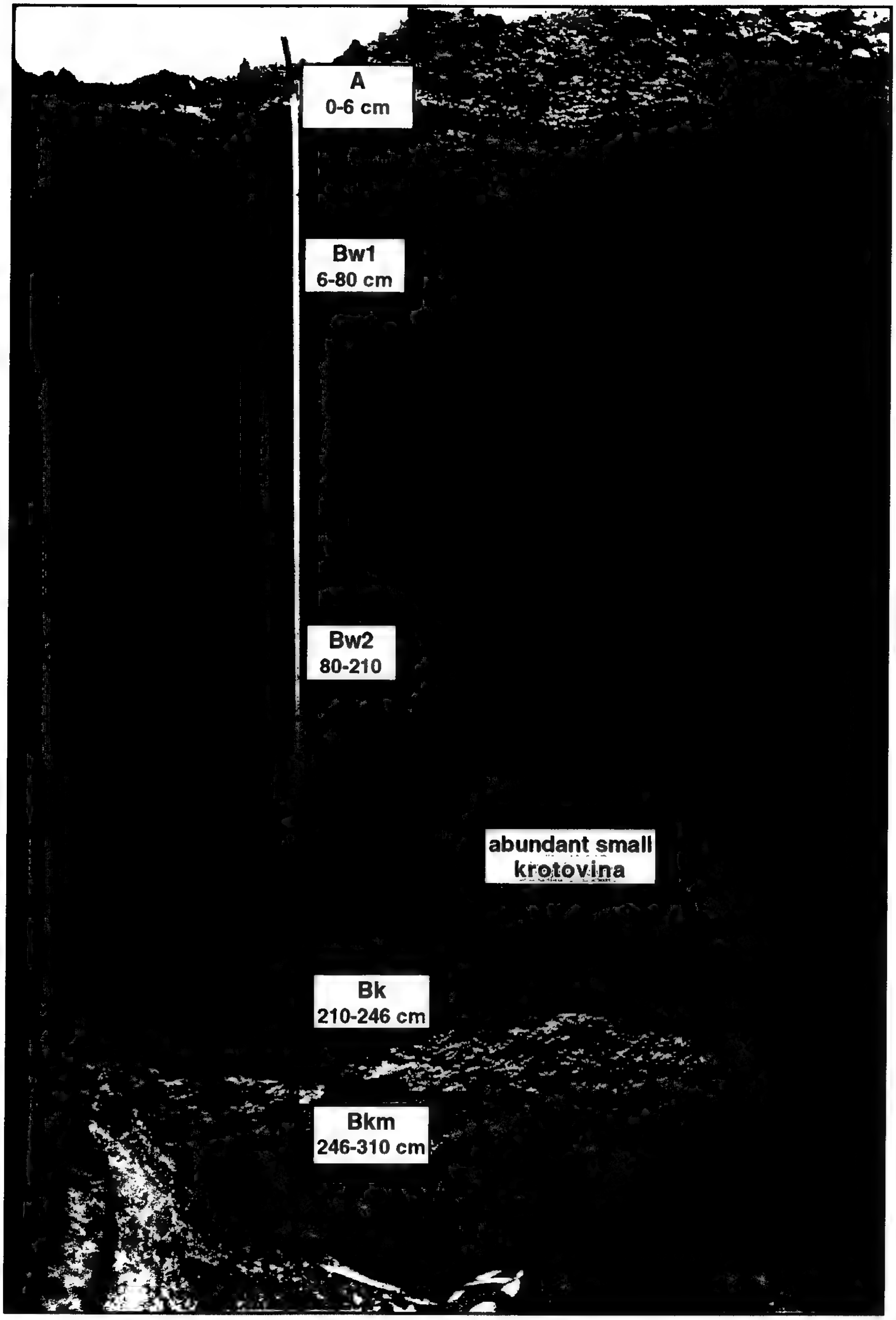


Figure 71. Range Control Depression, site 50, soil profile. This soil formed in undulating sheet sand, throughout and on the surface of which water-polished Camp Rice gravels are occasionally met, presumably brought up and dispersed into the sand sheet by bioturbation. Several termite sheaths formed vertically on the wall of this pit between the time it was dug in mid-May and when it was described in mid-June.

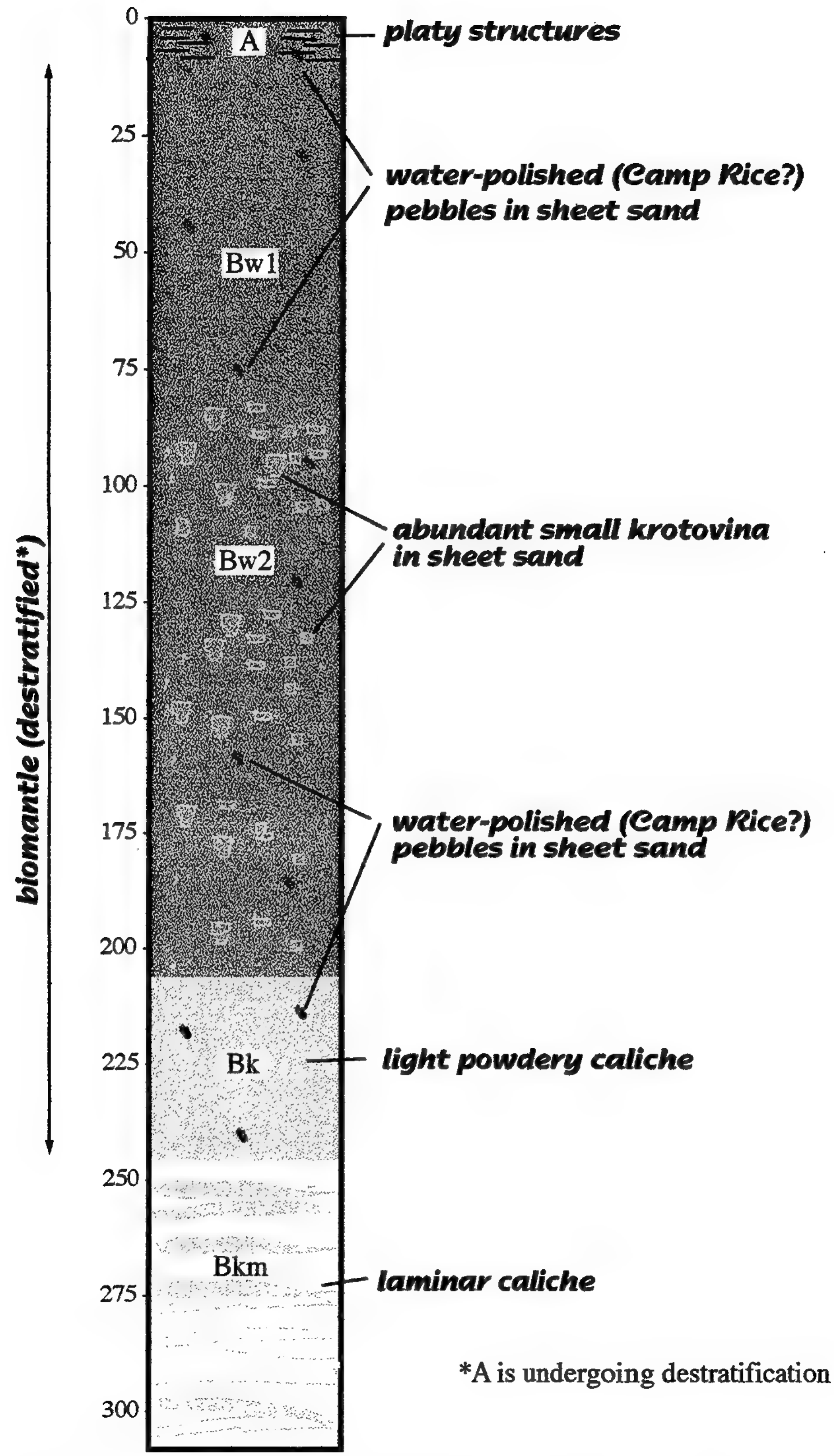


Figure 72. Profile schematic of site 50, Range Control Depression, McGregor Range, New Mexico.

Alvarado Lake (see Figure 28), such as occurred in 1941. The full sediment-soil description is in Appendix D, a photo of the described pedon is in Figure 73, and a profile schematic is in Figure 74. Three stratigraphic units occur here: a silty unit, over a sand sheet, over a silt loam unit, each of which has an immature, weakly expressed soil. The stratigraphy here suggests that at least some of the distal toeslope playas in this part of the Tularosa Basin are ephemeral (short-lived), and that normal valley dynamics include episodic faulting (down-dropping) of the Tularosa graben, episodic sheet sand migrations, and periodic wet trends and large storms, sometimes megastorms.

Although no stratigraphic or soil work was done in nearby Middle Playa or Snail Playa or their lunettes (see Figure 29), both have interesting surface phenomena that should at least be mentioned. For example, the lunette surfaces of Middle Playa and the un-named playa to its west (see Figure 29) have associated septarium-like calcium carbonate-precipitated nodules of various styles and geometries (Figure 75). These apparently form by percolating meteoric waters within the lunettes, followed by erosion of the lunettes which allows the nodules to become surface concentrated. Snail Playa, on the other hand, is of interest because it is one of the lowest lying playas in the area, and has at least five bathtub rings around it (see Figure 29) that represent changing lake levels.

The rings are testimony to the episodic nature of playa filling in the area. Shells of aquatic planorbid snails litter its surface and cover the lower three bathtub rings, strongly suggesting that the shells are related to one or more historic lake fillings (the wettest years were 1880s, 1904, 1941, 1958, 1984, and 1991, as indicated in Appendix B). The shells gave an almost certainly incorrect ^{14}C age of 790 ± 80 radiocarbon years before present, suggesting that the snails had somehow incorporated some amount of dead carbon in making their shells (the area receives dead carbonate runoff from Permian rocks to the north, east, and southeast). It is illuminating to note that separate radiocarbon dates on organic and inorganic carbon of the same kangaroo rat dung pellets at Dust Pit, site 40—which also receives dead carbonate runoff—gave disparate ^{14}C ages of $1{,}080 \pm 110$ and $9{,}200 \pm 70$ radiocarbon years before present, indicating that inorganic carbon (i.e., within-soil precipitated $CaCO_3$) can also yield spurious ages. Table 1 gives details of the date and sample, and Appendix A discusses the ^{14}C pretreatments employed and contains the ^{14}C submission sheets. All the playas in the area display abundant signs of prehistoric Native American activity (fire-cracked rock, hearths, artifacts, etc.).

Vertisol Playa, site 38, is in a depression on the east side of the railroad track that parallels Highway 54 between Desert and Alvarado (Desert quad, mapping unit Pl). It has multiple shorelines (bathtub rings), abundant evidence of prehistoric human activity, and aquatic planorbid snail shells that cover the playa floor and first bathtub ring. The full sediment-soil description is in Appendix D, photos of the playa are in Figures 76 and 77, chemical and particle size data are in Table 11, depth functions of particle size are in Figure 78, and a profile schematic that summarizes these data is in Figure 79.

A double handful of planorbid shells was collected from the playa floor for a group ^{14}C date. It was assumed that the shells had residually accumulated from one or several historic lake-filling events, perhaps during wet periods of the 1880s, 1904, 1941, 1958, 1984, and or 1991 (see Appendix B). The date gave a modern, very recent age value for the snails, for inasmuch as atomic bomb-generated ^{14}C was incorporated within their shells, they had to have lived after 1945. The date suggested that the snails lived in Vertisol Playa sometime between 1985 and 1995. Why these snail shells, unlike the Snail Playa shells, yielded apparently correct ^{14}C results is unclear. (Appendix A gives details of the snail shell pretreatment process.)

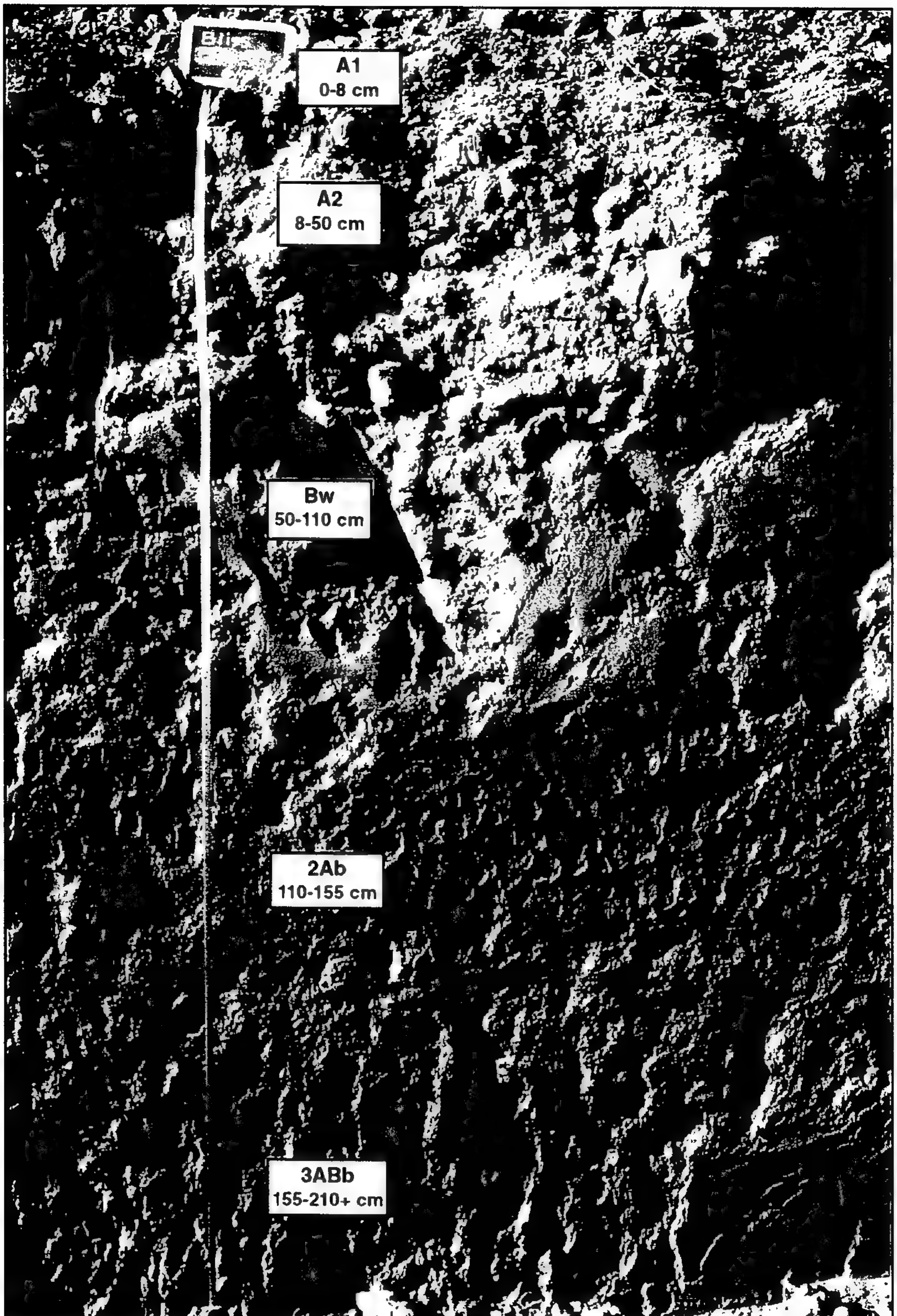


Figure 73. Alvarado Tank No. 2, site 39, soil profile. The 2Ab and 3ABb horizons are superposed buried soils formed in dune sheet sand and silt loam units. The stratigraphy here suggests that at least some of the distal toeslope playas in this part of the Tularosa Basin are ephemeral, and that basin dynamics reflect episodic Tularosa graben faulting (down-dropping), episodic dune sand migrations, and possibly climatic change and/or megastorm events.

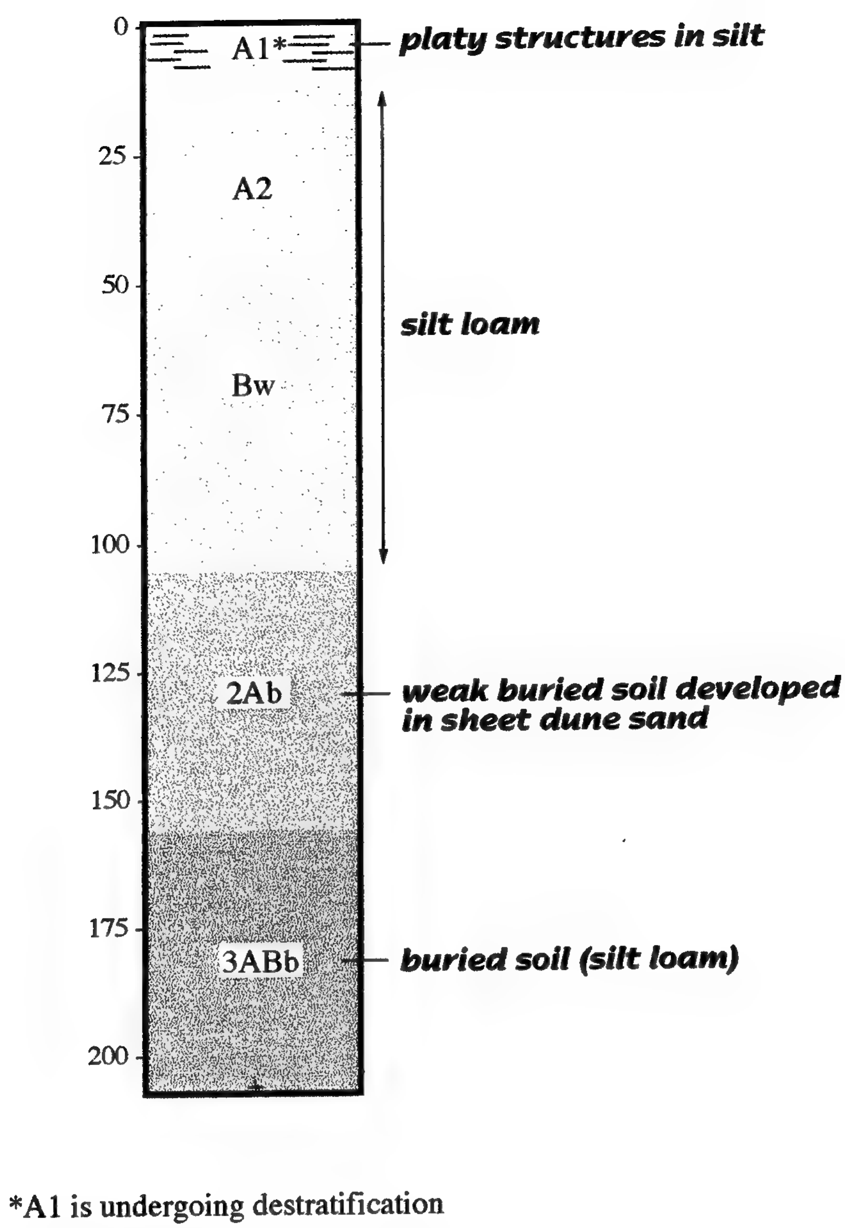


Figure 74. Profile schematic of site 39, Alvarado Tank No. 2, McGregor Range, New Mexico.

Dr. Stephen A. Hall also sampled the profile here for pollen analysis. The following is his report (personal communication 1996):

> Vertisol Playa. The basal sample contains lots of pollen, moderately preserved, with many charred particles but without the fluffy organic debris of Lake Tank Playa. The pollen is suitable for scientific study, but I wonder about the integrity of the vertisol environment. One way to test its integrity is to AMS date several zones to see what the ^{14}C age variation might be.

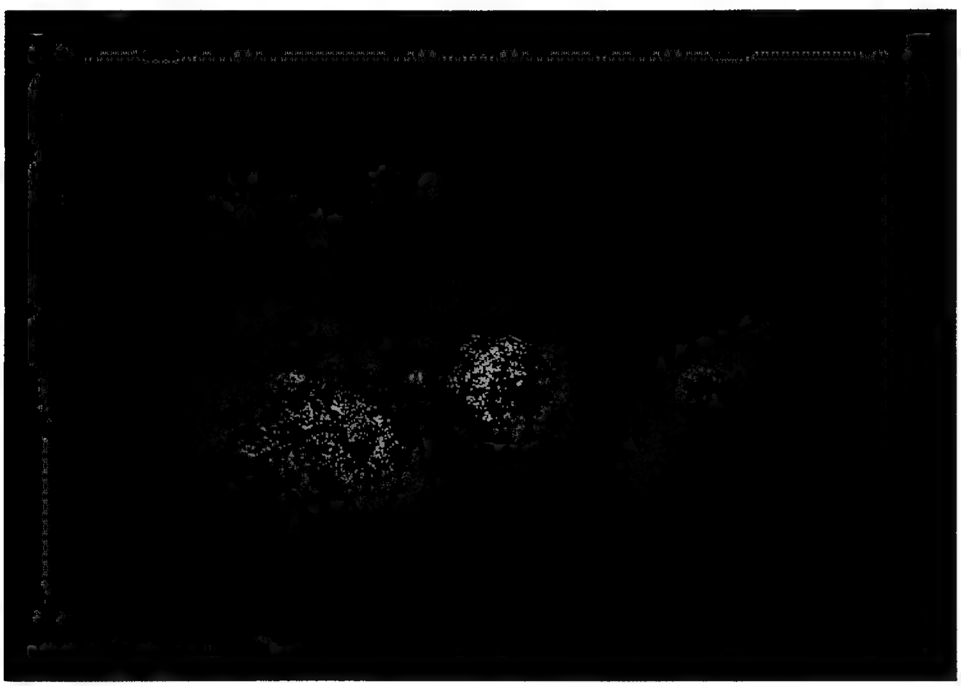
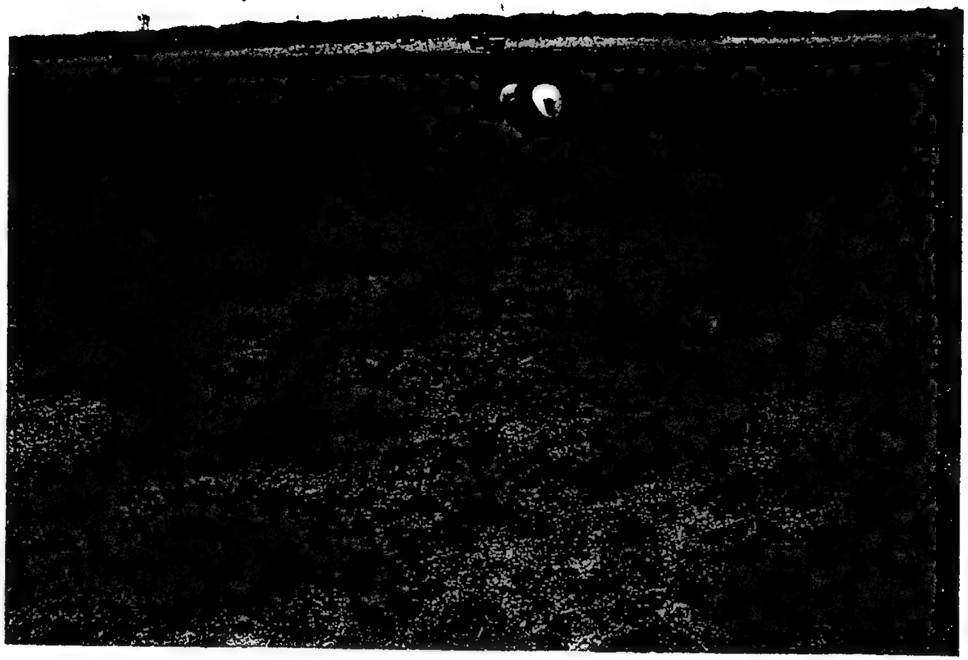


Figure 75. Photos from Middle Playa, which lies to the west of Alvarado Tank No. 2. Upper photo shows the character of the lunette surface of Middle Playa. This surface is similar to the surface of another lunette associated with the un-named playa to its west. Both have septarian-like calcium carbonate-precipitated nodules of various styles and geometries precipitated within their lunette dunes (bottom photo). They apparently form by percolating, bicarbonate-charged meteoric waters within the lunettes where the nodules are precipitated, followed by erosion and wasting of the lunettes, which concentrates the nodules at the surface as a lag.



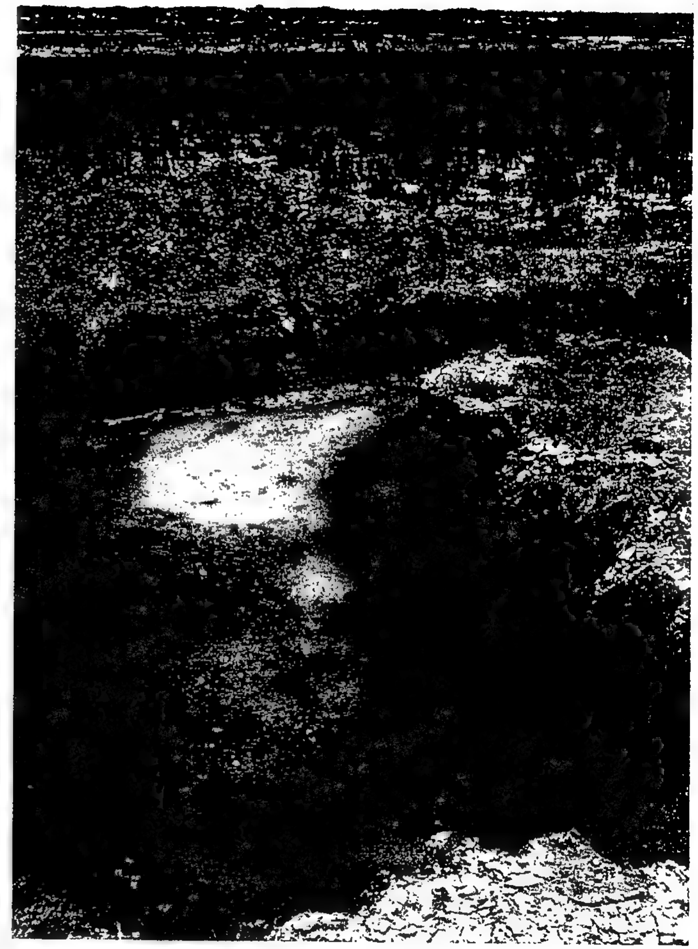


Figure 76. Two views of Vertisol Playa next to the Southern Pacific Railroad track north of Alvarado. Left photo shows the excessively cracked floor of the playa that is clearly due to shrinking smectite rich clays that dominate the fine fraction of the playa sediment. Note manuports and artifacts scattered about on the playa surface. The backhoe pit dug to describe and sample the sediments can be seen in the left background near the truck. Right photo shows the backhoe pit filled with water from rains that had fallen between June 14, when the pit was dug, and July 27 when this photo was taken.

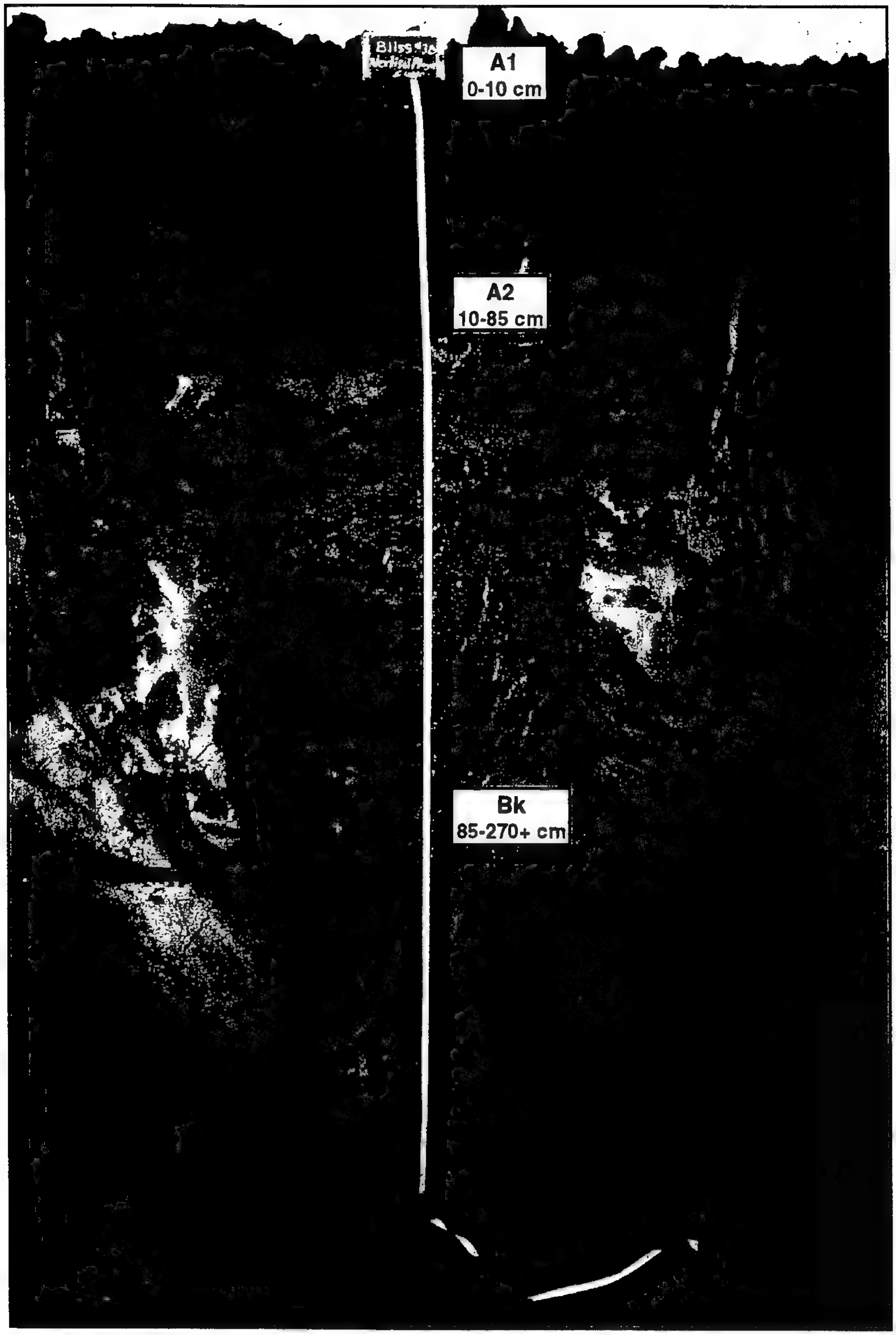


Figure 77. Vertisol Playa, site 38, soil profile. Fire-cracked rock, occasional potsherds, and evidence of wasted hearths are present on the playa floor and at various levels along the northern side, and may or may not be associated with higher strandlines there. A radiocarbon date on empty shells of a Planorbid (aquatic) snail indicates that the last significant flooding was post-1945. The shells are abundant on the playa floor to a bench 6 ft above it. When described, the playa had cracks 180 cm deep and 14 cm wide that defined large polygons. Cracks infilled with organic debris and mulched (granulated) soil apparently form upon drying from summer rains, but appear not to reform in previous cracks. The backhoe pit was described and sampled on June 14, 1996, but when revisited on July 27 it was filled with water from recent rains.

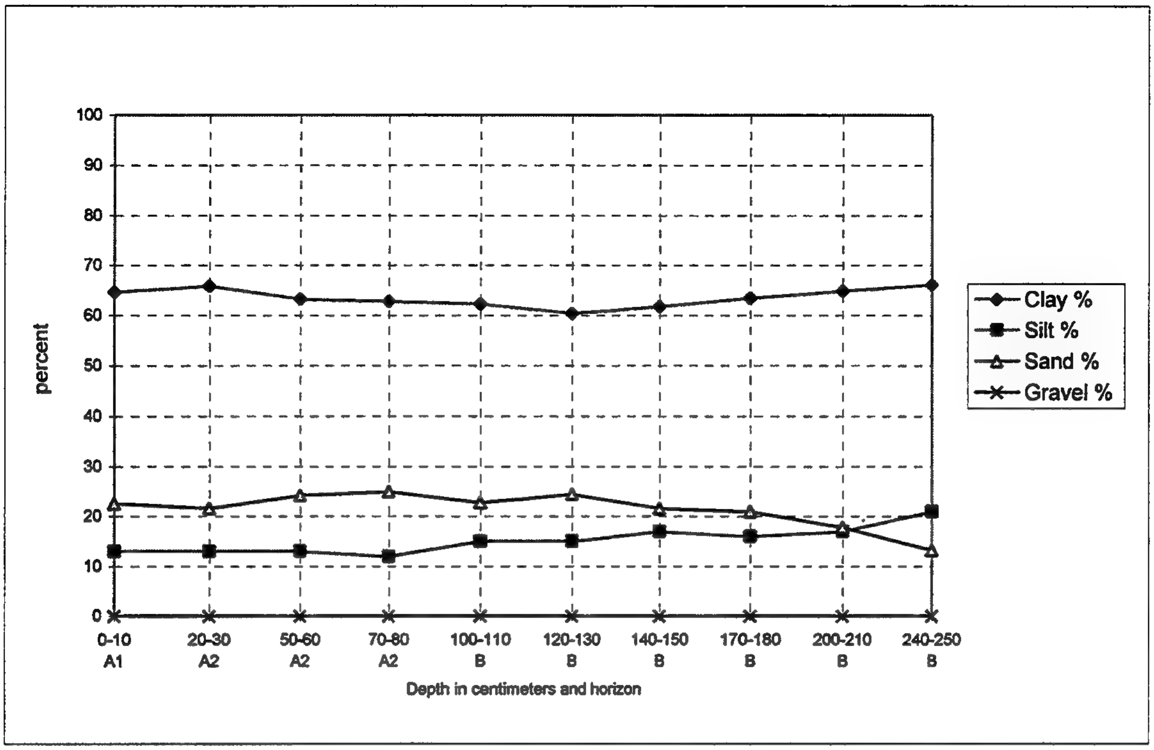
Table 11
Vertisol Playa, Site 38, McGregor Range, New Mexico
Particle Size and Chemical Data

Particle Size Data

Horizon	Depth	Sediment / Percent: Clay	Silt	Sand	Fine Silt	Coarse Silt	Very Fine Sand	Fine Sand	Medium Sand	Coarse Sand	Very Coarse Sand	Gravel	Textural Class
A1	0-10	64.70	13.00	22.60	11.10	1.60	10.40	8.70	2.40	0.90	0.10	0.00	C
A2	20-30	65.90	13.00	21.60	12.00	0.60	10.70	8.40	1.60	0.60	0.20	0.00	C
A2	50-60	63.30	13.00	24.20	10.20	2.40	11.50	9.60	2.20	0.80	0.10	0.00	C
A2	70-80	62.80	12.00	25.00	10.00	2.30	11.30	10.30	2.20	1.00	0.10	0.00	C
B	100-110	62.30	15.00	22.80	10.50	4.40	10.10	9.50	2.20	0.90	0.10	0.00	C
B	120-130	60.40	15.00	24.50	10.80	4.20	10.50	10.80	2.20	0.90	0.10	0.00	C
B	140-150	61.80	17.00	21.60	11.40	5.20	9.90	8.70	2.20	0.80	0.10	0.00	C
B	170-180	63.50	16.00	21.00	12.00	3.50	10.30	8.10	1.90	0.60	0.10	0.00	C
B	200-210	64.90	17.00	17.80	11.40	5.80	8.50	6.80	1.70	0.80	0.10	0.00	C
B	240-250	66.10	21.00	13.30	13.80	6.80	6.80	5.30	0.90	0.30	0.10	0.00	C

Chemical Data

Horizon	Depth	Ca meq/100g	Mg meq/100g	Na meq/100g	K meq/100g	Sum of Bases meq/100g	Acidity meq/100g	Al meq/ 100g	CEC by sum of cations meq/100g	CEC-7 (NH4OAc) meq/100g	CEC Bases + Al	Al Sat %	Base Sat by sum %	Base Sat by CEC-7 %	Organic Carbon %	Salt pH .01M CaCl2	Water pH
A1	0-10	52.70	6.20	0.30	1.80	61.00	0.00	--	61.00	32.10	--	--	100.00	100.00	0.30	7.40	7.70
A2	20-30	56.40	7.00	0.30	1.90	65.60	0.00	--	65.60	31.30	--	--	100.00	100.00	0.30	7.50	7.90
A2	50-60	56.60	7.40	0.70	1.90	66.60	0.00	--	66.60	31.50	--	--	100.00	100.00	0.30	7.50	8.00
A2	70-80	55.00	7.70	1.20	1.80	65.70	0.00	--	65.70	31.20	--	--	100.00	100.00	0.20	7.60	8.00
B	100-110	51.80	8.50	2.20	1.90	64.40	0.00	--	64.40	31.60	--	--	100.00	100.00	0.20	7.70	8.10
B	120-130	53.80	8.60	3.10	1.90	67.40	0.00	--	67.40	31.60	--	--	100.00	100.00	0.20	7.70	8.10
B	140-150	52.30	8.50	3.20	1.80	65.80	0.00	--	65.80	31.70	--	--	100.00	100.00	0.20	7.70	8.10
B	170-180	54.20	8.60	4.10	1.90	68.80	0.00	--	68.80	32.40	--	--	100.00	100.00	0.20	7.80	8.10
B	200-210	54.40	8.20	4.50	1.90	69.00	0.00	--	69.00	32.50	--	--	100.00	100.00	0.20	7.80	8.00
B	240-250	59.00	7.30	4.20	1.70	72.20	0.00	--	72.20	33.80	--	--	100.00	100.00	0.10	7.60	7.80



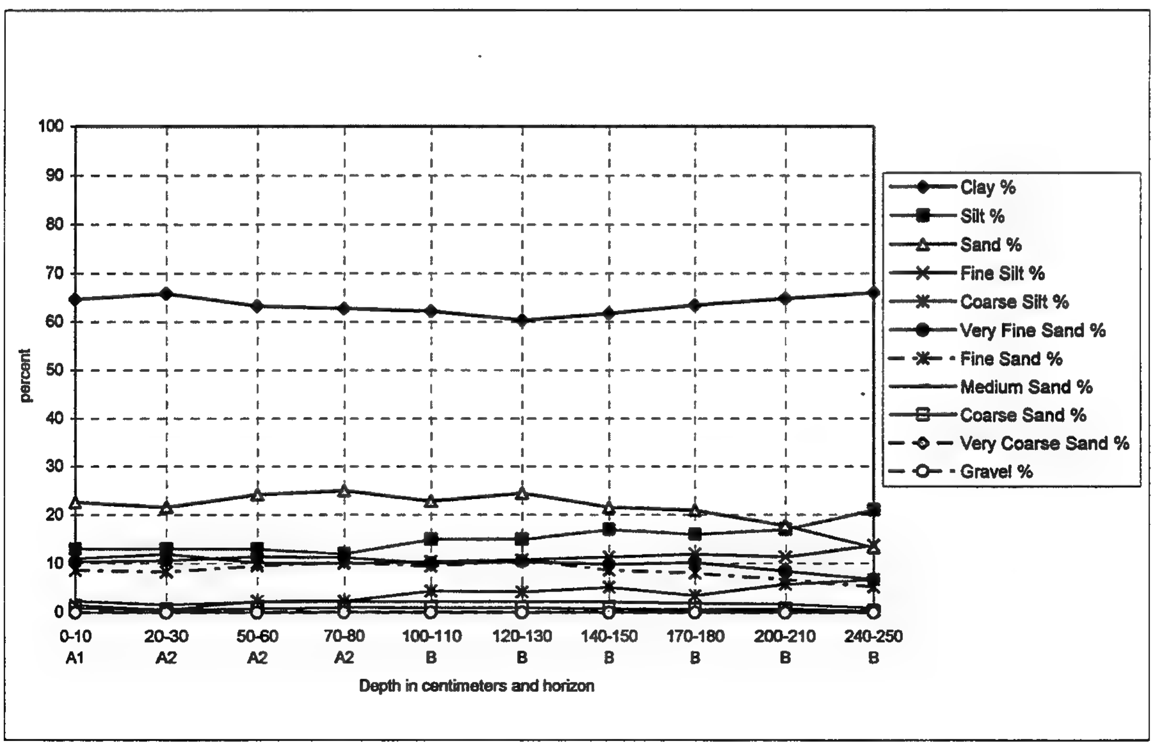


Figure 78. Vertisol Playa, site 38, depth functions of four (upper) and 11 (lower) particle sizes (a few gravels were observed in the described pit wall but were not present in sediment samples collected for laboratory analysis; data from Table 11).

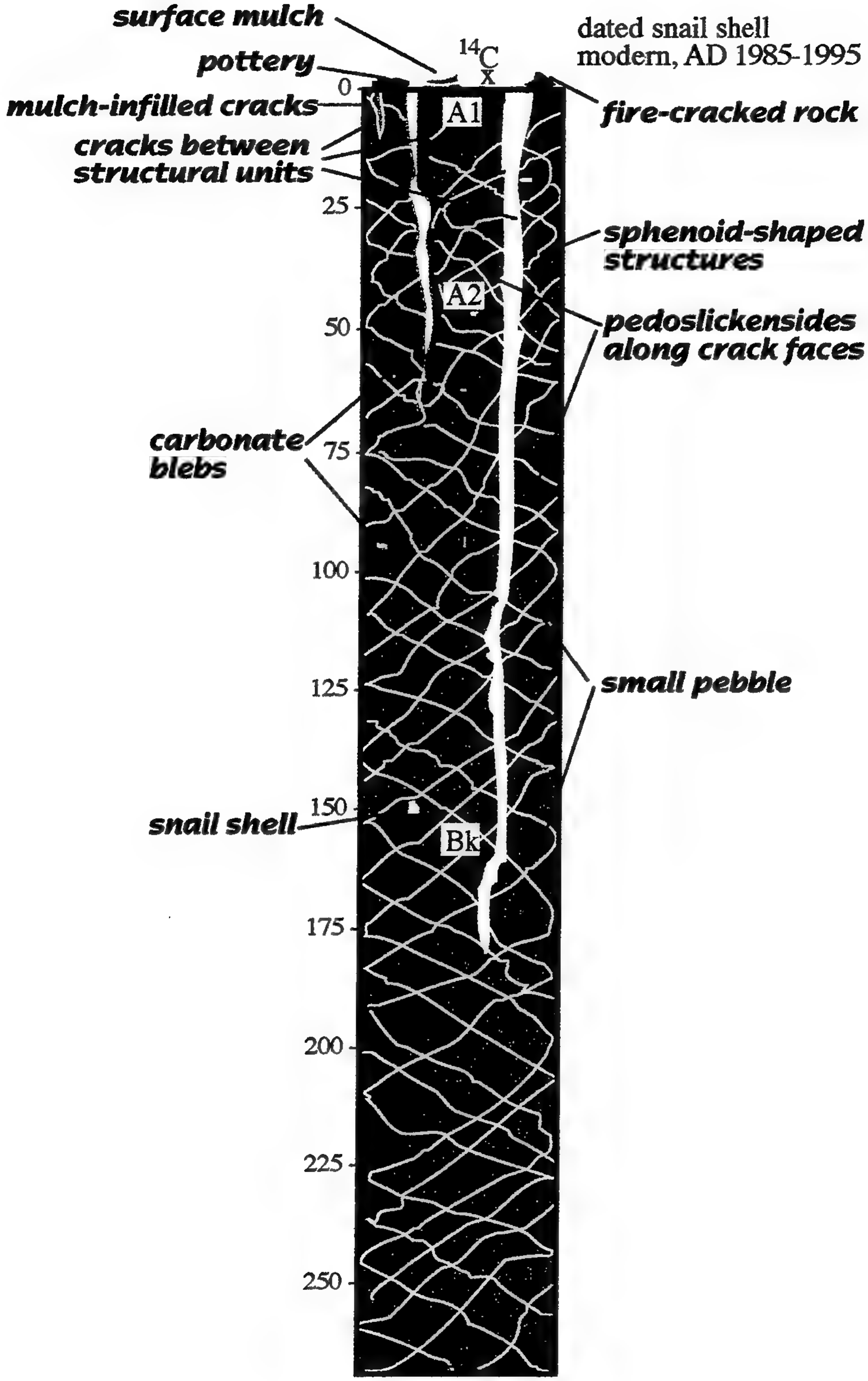


Figure 79. Profile schematic of site 38, Vertisol Playa, McGregor Range, New Mexico.

Gypsum Playa, site 37, lies in a depression on the northwest side of the Desert-to-South Well road, 1.3 miles (2.1 km) east of Desert. It too has abundant evidence of prehistoric human activity and suggestive evidence of bathtub rings. The full sediment-soil description is in Appendix D, photos of the described pedon are in Figures 80 and 81, chemical and particle size data are in Table 12, depth functions of the particle size data are in Figure 82, and a profile schematic summarizing these data is in Figure 83.

Figure 84 shows a badger burrow and mound in the area northeast of Desert where artifacts have been moved from the subsurface to the surface. During the course of this study, many such observations of displaced artifacts associated with badger burrowing have been made.

Broken Escarpment Zone

This zone encompasses the area between Otero Mesa and the Sacramento Mountains on the east and the Tularosa Basin on the west, and extends on McGregor from Negro Ed Canyon on the north to the Hueco Mountains on the south. It includes the normal faults on the east side of the Tularosa Basin that are partly responsible for the basin itself. It includes the Hueco Bedrock Finger south of the Jarilla Gap, and two faultline depressions and playas immediately east and southeast of Davis Dome (Faultline and Lake Tank playas).

A number of faults occur in the Broken Escarpment and are major contributing factors to the general character of this zone. Some were listed above (see the discussion on Structure and Faults), but many others doubtless exist that were not listed or noted in this study. The most conspicuous are those in the north of this zone, especially between County Road 506 and Bug Scuffle Canyon (see Figures 16 and 18). The most obvious are Pipeline Fault No. 1, Culp, Grapevine faults, and W. Grapevine Fault. All three project to the southwest toward the Jarilla Mountains and are generally aligned with the inferred (unverified) Jarilla Bolson Fault (Orogrande S quad). The Jarilla faults described by Herrick and Davis (1965) that strike northeast could represent a family of faults related in style and motion to the Pipeline, Culp, and Grapevine family of faults.

On another fault-related matter, normal (basin side, down mountain side, up) movements along Culp Fault have created several conspicuous paleofans that were once active depositional surfaces of the streams emanating from Bug Scuffle, Grapevine, and Culp canyons (see Figures 16 and 18; for ease of communication they have been named, from north to south, Grapevine-Bug Scuffle, Grapevine, North Culp, and South Culp paleofans, see Figure 18). Normal fault movements have in fact systematically beheaded fans emanating from these canyons, where their ancient fanheads are now relict. That each was beheaded at a different time is manifest by their relative degrees of dissection, which based on this criterion occurred in the following sequence: first North Culp, then South Culp, then Grapevine-Bug Scuffle, and last Grapevine. A caveat is that while the Grapevine-Bug Scuffle paleofan was field-checked on site and verified as such, and Grapevine paleofan is unquestionably a paleofan as observed in the field from a distance and as inferred from air photos, the North Culp and South Culp paleofans are uncertain. They were not field-checked, but on air photos they exhibit all the signatures of dissected paleofans (see Figures 15 and 18). An alternative explanation for these two landforms is that they were paleofans but are now so dissected and eroded that much, most, or all the original fluvial gravels are gone, revealing an eroded bedrock pediment with an inherited dissection drainage pattern.

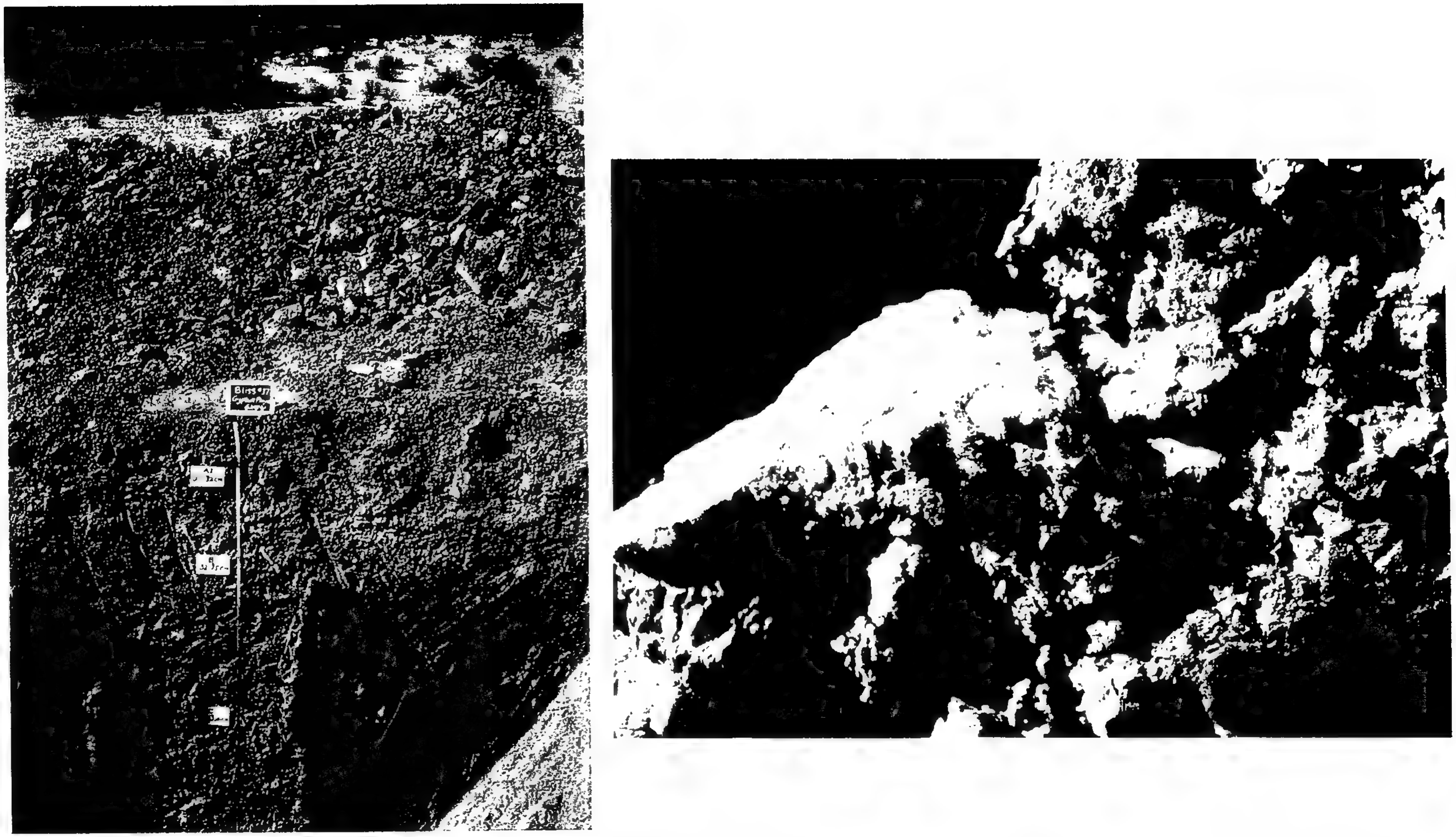


Figure 80. The backhoe pit at Gypsum Playa, site 37, so named because the playa sediments are gypsum rich. The right photo is a close-up of a selenite precipitated zone that is visible in the lower left portion of the profile in the left photo.

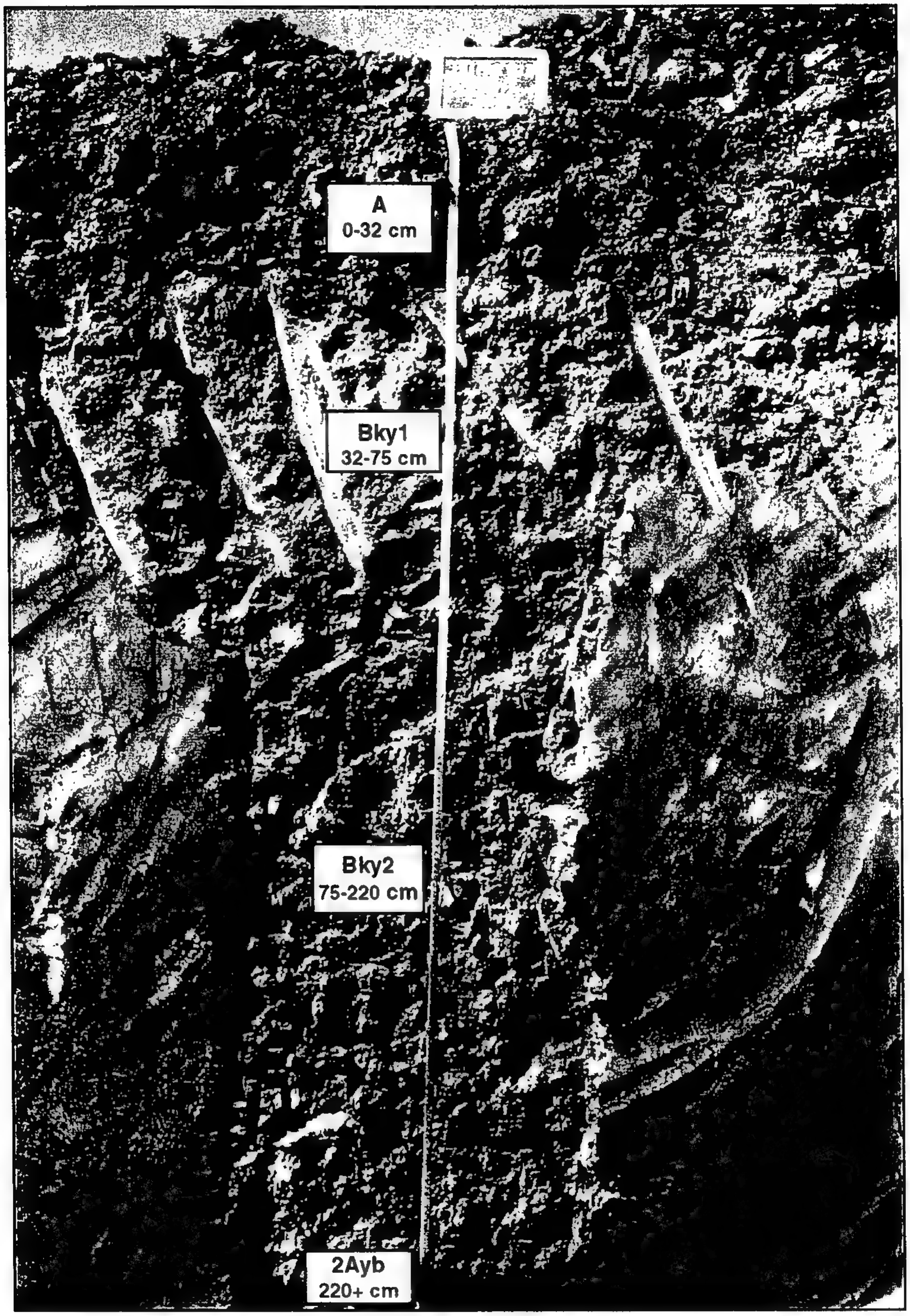


Figure 81. Gypsum Playa, site 37, soil profile. This gypsum-enriched playa has abundant sites with fire-cracked rock on perimeter shorelines, but whether the sites are chronologically related to the strandlines is uncertain. It may be the southernmost of the gypsum playas that are common farther north, especially on the west, north, and east sides of the Jarilla Mountains (e.g., Salt Cedar Playa, Cox Well Playa, Lone Butte Playa, Great Wall of China Playa, etc.). Gypsum may be washing in as airfall gypsiferous dust, leaching downward to the watertable, then wicking up into the playa sediments (the bottom of the pit was moist). Selenite has precipitated into large crystalline masses in the Bky2 horizon, and as vertical filaments and veinlets of caliche and gypsum from the bottom of the A1 to the upper Bky2 horizon.

Table 12
Gypsum Playa, Site 37, McGregor Range, New Mexico
Particle Size and Chemical Data

Particle Size Data

Horizon	Depth	Clay	Silt	Sand	Fine Silt	Coarse Silt	Very Fine Sand	Fine Sand	Medium Sand	Coarse Sand	Very Coarse Sand	Gravel	Textural Class
		Sediment / Percent											
A	0-10	33.20	16.00	50.40	9.20	7.10	18.80	25.00	5.60	1.00	0.10	0.00	SCL
A	10-20	32.70	15.00	52.40	8.60	6.40	20.40	26.70	4.30	0.90	0.10	0.00	SCL
A	20-32	37.50	16.00	46.60	10.00	5.80	18.40	22.60	4.60	0.80	0.20	0.00	SC
Bky1	32-40	2.40	54.00	43.20	46.20	8.10	5.10	22.00	6.10	4.80	5.10	0.00	SIL
Bky1	40-50	1.90	50.00	47.70	41.90	8.50	9.80	18.40	4.60	6.90	8.00	0.00	SIL
Bky1	50-60	1.80	48.00	50.40	40.10	7.70	15.20	18.30	4.80	4.40	7.60	0.00	FSL
Bky1	60-75	1.30	52.00	47.00	43.20	8.60	14.00	16.70	2.80	4.00	9.50	0.00	SIL
Bky2	75-90	44.20	19.00	36.90	12.40	6.50	16.80	17.40	2.20	0.50	0.00	0.00	C
Bky2	90-100	47.30	21.00	32.00	14.90	5.80	15.90	13.90	1.90	0.30	0.00	0.00	C
Bky2	110-120	47.70	20.00	32.30	14.50	5.60	16.30	14.90	1.00	0.10	0.00	0.00	C
Bky2	130-140	2.60	72.00	25.40	65.50	6.50	9.20	10.70	1.50	2.30	1.70	0.00	SIL
Bky2	150-160	57.20	22.00	20.70	16.40	5.70	10.40	9.30	0.90	0.20	0.00	0.00	C
Bky2	170-180	55.20	25.00	20.00	17.10	7.70	10.60	8.60	0.70	0.00	0.00	0.00	C
Bky2	190-200	58.50	26.00	15.50	19.30	6.80	9.20	5.70	0.50	0.00	0.00	0.00	C
Bky2	210-220	64.10	26.00	10.40	20.70	4.80	6.70	3.20	0.30	0.10	0.10	0.00	C
2Ayb	220+												

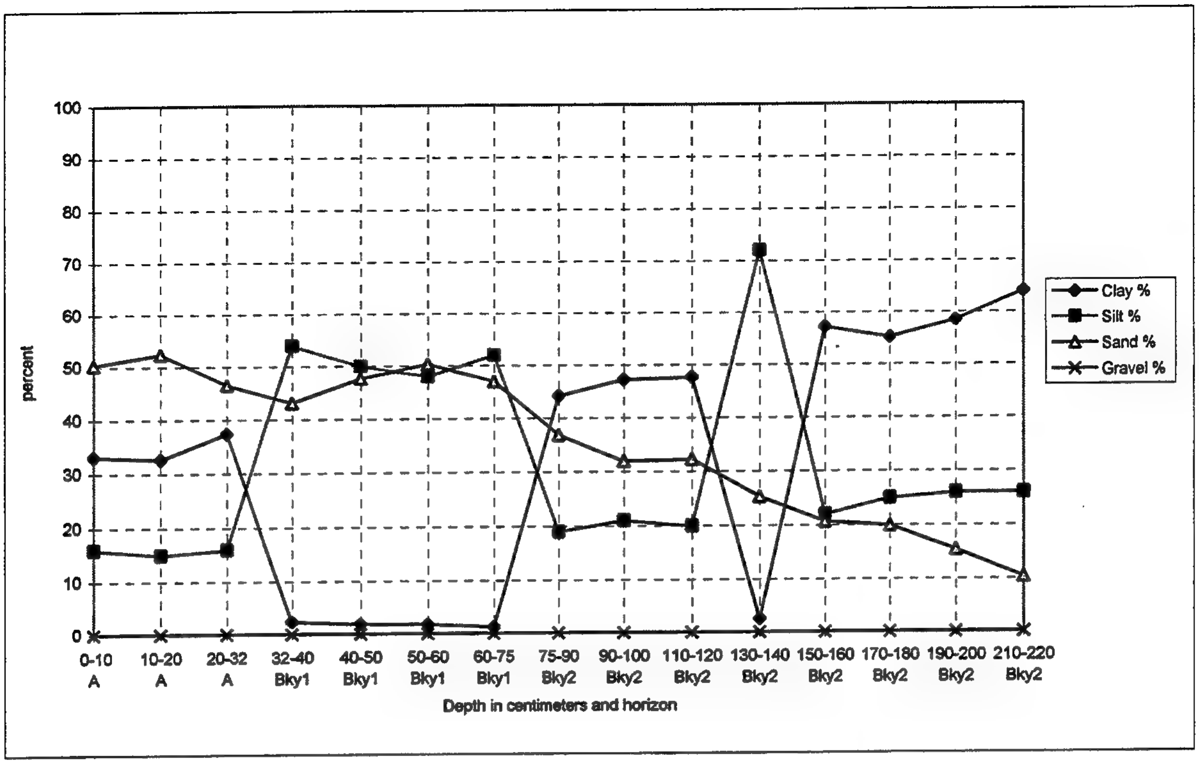
Chemical Data

Horizon	Depth	Ca meq/100g	Mg meq/100g	Na meq/100g	K meg/100g	Sum of Bases meq/100g	Acidity meq/100g	Al meq/100g	CEC by sum of cations meq/100g	CEC-7 (NH4OAc) meq/100g	CEC Bases + Al	Al Sat %	Base Sat by sum %	Base Sat by CEC-7 %	Organic Carbon %	Salt pH .01M CaCl2	Water pH
A	0-10	44.00	5.20	11.50	0.60	61.30	0.00	--	61.30	19.40	--	--	100.00	100.00	0.30	8.00	8.20
A	10-20	40.10	5.50	13.10	0.60	59.30	0.00	--	59.30	20.10	--	--	100.00	100.00	0.20	7.90	8.20
A	20-32	57.50	7.50	15.80	0.60	81.40	0.00	--	81.40	21.10	--	--	100.00	100.00	0.20	7.70	7.90
Bky1	32-40	138.00	7.40	13.90	0.60	160.00	0.00	--	160.00	20.40	--	--	100.00	100.00	0.10	7.70	7.80
Bky1	40-50	149.00	8.10	13.30	0.50	171.00	0.00	--	171.00	19.50	--	--	100.00	100.00	0.10	7.70	7.90
Bky1	50-60	142.00	8.70	15.10	0.50	167.00	0.00	--	167.00	19.70	--	--	100.00	100.00	0.10	7.70	7.90
Bky1	60-75	145.00	9.30	18.40	0.50	173.00	0.00	--	173.00	21.10	--	--	100.00	100.00	0.10	7.90	8.10
Bky2	75-90	70.20	10.30	20.80	0.50	101.00	0.00	--	101.00	25.20	--	--	100.00	100.00	0.10	8.00	8.20

Table 12 (cont'd)

Chemical Data

Horizon	Depth	Ca meq/100g	Mg meq/100g	Na meq/100g	K meg/100g	Sum of Bases meq/100g	Acidity meq/100g	Al meq/ 100g	CEC by sum of cations meq/100g	CEC-7 (NH4OAc) meq/100g	CEC Bases + Al	Al Sat %	Base Sat by sum %	Base Sat by CEC-7 %	Organic Carbon %	Salt pH .01M CaCl2	Water pH
Bky2	90-100	66.20	10.50	19.70	0.60	97.00	0.00	--	97.00	25.70	--	--	100.00	100.00	0.10	8.00	8.10
Bky2	110-120	38.70	10.20	24.60	0.60	74.10	0.00	--	74.10	28.40	--	--	100.00	100.00	0.10	8.50	8.60
Bky2	130-140	103.00	10.60	28.20	0.60	142.00	0.00	--	142.00	30.60	--	--	100.00	100.00	0.10	7.90	8.00
Bky2	150-160	48.10	11.00	28.00	0.70	87.80	0.00	--	87.80	31.90	--	--	100.00	100.00	TR	8.10	8.30
Bky2	170-180	38.20	10.80	28.90	0.70	78.60	0.00	--	78.60	32.40	--	--	100.00	100.00	0.10	8.50	8.50
Bky2	190-200	36.30	10.20	25.30	0.60	72.40	0.00	--	72.40	31.60	--	--	100.00	100.00	TR	8.50	8.50
Bky2	210-220	52.60	8.80	20.80	0.50	82.80	0.00	--	82.80	26.50	--	--	100.00	100.00	TR	7.90	8.10



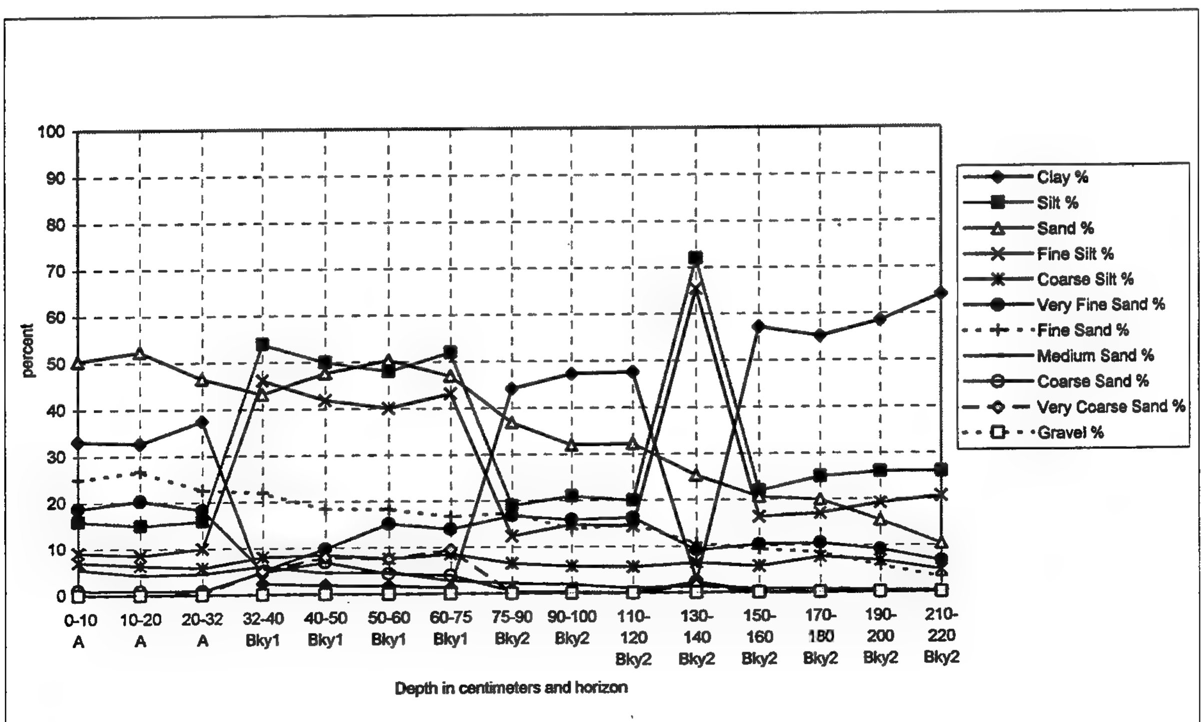


Figure 82. Gypsum Playa, site 37, depth functions of particle sizes: (upper) four and (lower) 11 (gravels were not present; data from Table 12).

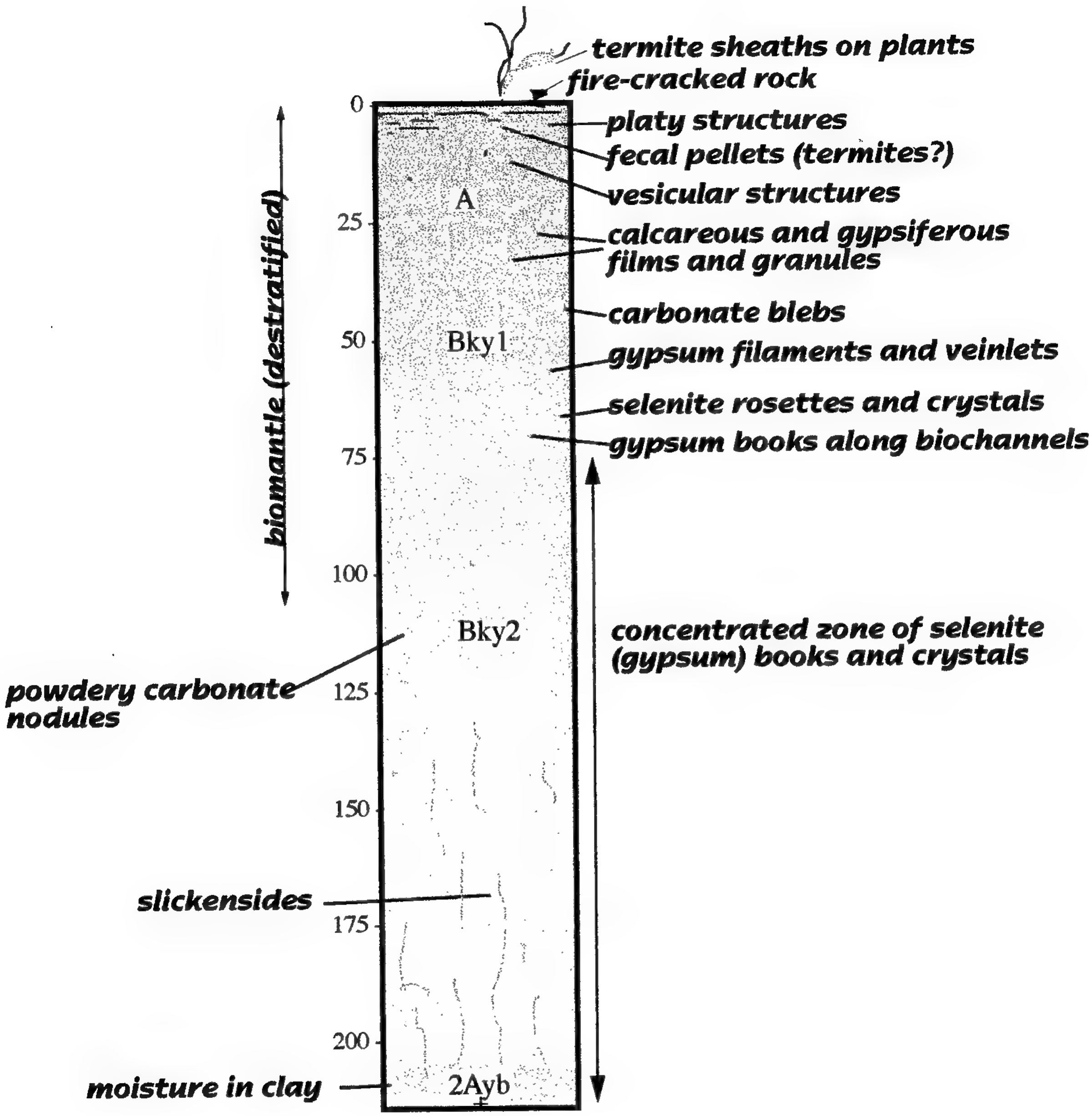


Figure 83. Profile schematic of site 37, Gypsum Playa, McGregor Range, New Mexico.

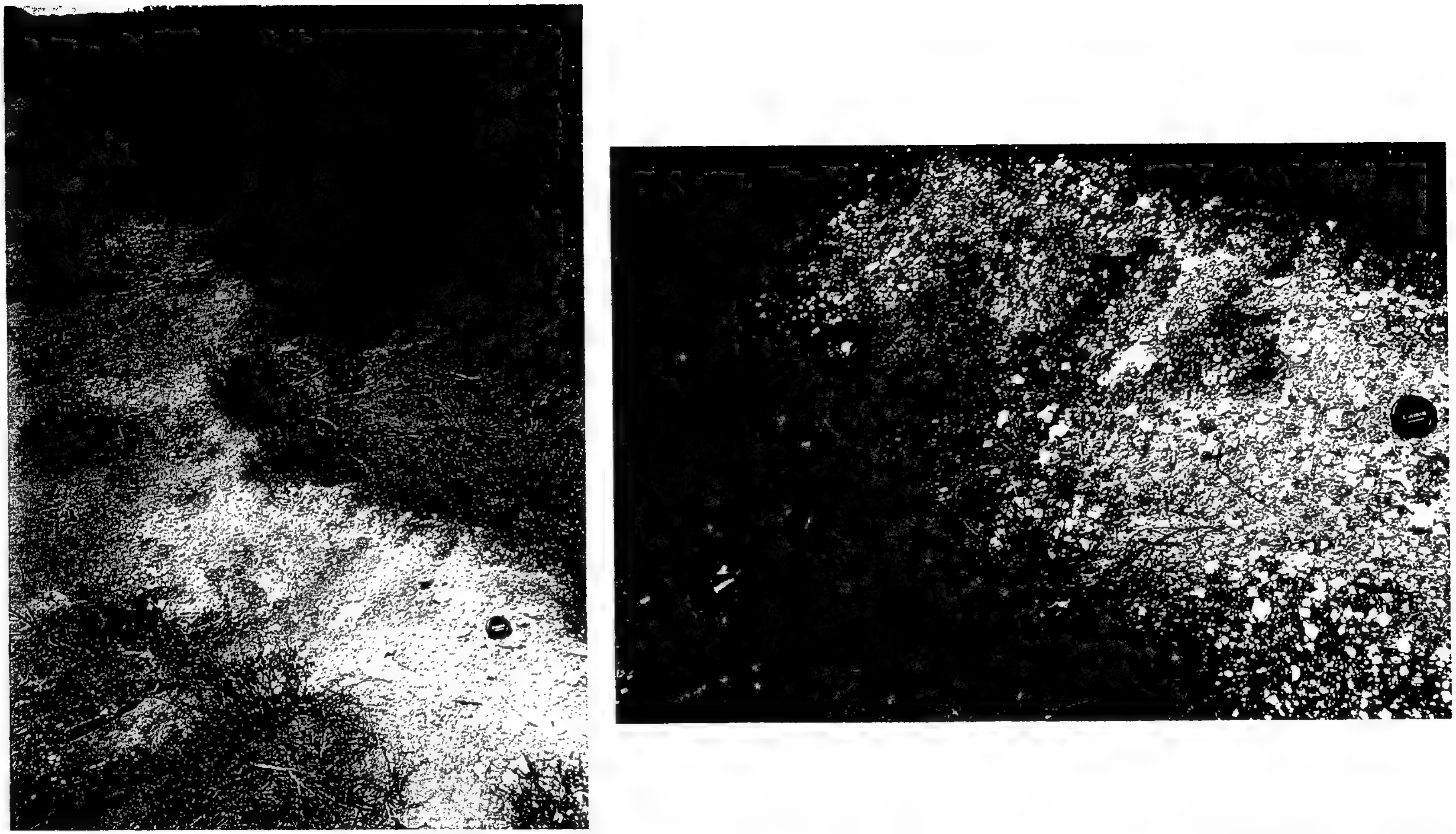


Figure 84. Two views of a badger burrow in the general Gypsum Playa area, north of Desert and east of the Perimeter Road that parallels the railroad tracks, on the north side of a depression around which abundant fire-cracked rock and prehistoric sites occur. The badger had obviously dug down to the calcic horizon, but in the process s/he excavated several fine grained quartzitic artifacts. The knife tip points to one artifact and the camera lens cap is to the right of another. McGregor Range, New Mexico.

In addition to faults, the following sites were investigated in detail in the Broken Escarpment Zone: Lake Tank Playa, Pluton Pit, Stone School, Dust Pit, Twin Pits, and Sulphur Tank.

1. *Lake Tank Playa, site 44.* This playa is 8 km (5 mi) southeast of Davis Dome in the southcentral part of McGregor (Desert SE quad, mapping unit Pl, see Figures 31 and 32). It is a faultline playa that receives almost all its water and sediment during stormflow periods from streams flowing out of the Hueco Mountains and Broken Escarpment area. During exceptional storms and wet periods it contains a lake that coalesces with a large linear lake in Faultline depression immediately to the northwest (see Figures 31 and 32). Its playa floor sediments are nonvertisolic: that is, they do not shrink and swell (argilliturbate) and are not distorted and mixed; they have stratigraphic integrity. Because they do not argilliturbate they contain an important record of past environments for the Hueco Mountains and Broken Escarpment areas. The full sediment-soil description is in Appendix D, Figure 85 is a photo of the profile, Table 13 gives the chemical and physical data, Figure 86 is depth functions of the particle size data, and Figure 87 is profile schematic that summarizes these data.

Dr. Stephen A. Hall, also sampled this pit for pollen and found abundant well-preserved pollen. His conclusions are as follows (personal communication 1996):

> Lake Tank Playa. I would have never guessed that this modest looking playa would have anything. But, the basal sample is loaded with lots of well preserved pollen. It is the best material I have seen from the El Paso area (except the twentieth century coppice dune and woodrat midden). It is a good candidate for a research-level study. Of course age is everything. As it turns out, a 20-gram chunk of mud from the playa has more than enough organics for a good AMS date, on solid organic matter (equivalent to the pollen residue). Every pollen sample has enough organic matter for an AMS date; we could get a date for every decimeter of the playa.

Two of Hall's extracted pollen samples, from depths of 100-110 cm and 180-190 cm, were AMS (accelerator) dated and, respectively, gave corrected ages of $2{,}730 \pm 60$ and $5{,}280 \pm 60$ radiocarbon years before present (see Table 1). Details of the pollen extraction method is given under Remarks at the end of the soil description (see Appendix D), and the pollen and ^{14}C data are in Appendix A and Table 1.

The significance of the Lake Tank site is that: (1) no evidence of mixing (argilliturbation, bioturbation, etc.) or other contamination problems exists; (2) because preserved pollen is present, the Holocene and later Pleistocene (at least) vegetation and human-prehuman environment of this part of the southeastern Tularosa Basin and Hueco Mountains can be generally reconstructed at high levels of resolution; (3) such a reconstruction can also be dated at high levels of resolution; and (4) such a reconstruction would be independent of, and augment, reconstructions based on pack rat midden analysis in the area.

2. *Pluton Pit, site 46.* This site is at the summit of a low divide on a road that runs from Lake Tank to Meyer Small Arms Range (A1-A3 mapping unit). It is 1.75 miles southwest of Lake Tank and is named for the small early-mid-Tertiary syenite intrusive pluton that outcrops on a limestone residual about 1 km to the south. Abundant surface evidence of vertebrate and invertebrate bioturbation exists (burrows, mounds, upturned calichified clasts, etc.). One pedon was described in the backhoe pit, and the description is in Appendix D. In another, which was essentially identical in general respects to the first, the horizon boundaries were vertucally demarcated. Both pedons were sampled, and the samples chemically and physically characterized in the laboratory. Figure 88 is a photo of the profile, the chemical and particle size data are in Table 14, and depth function graphs of particle size for the two profiles are in Figures 89 and 90. Figure 91 is a profile schematic that summarizes these data.

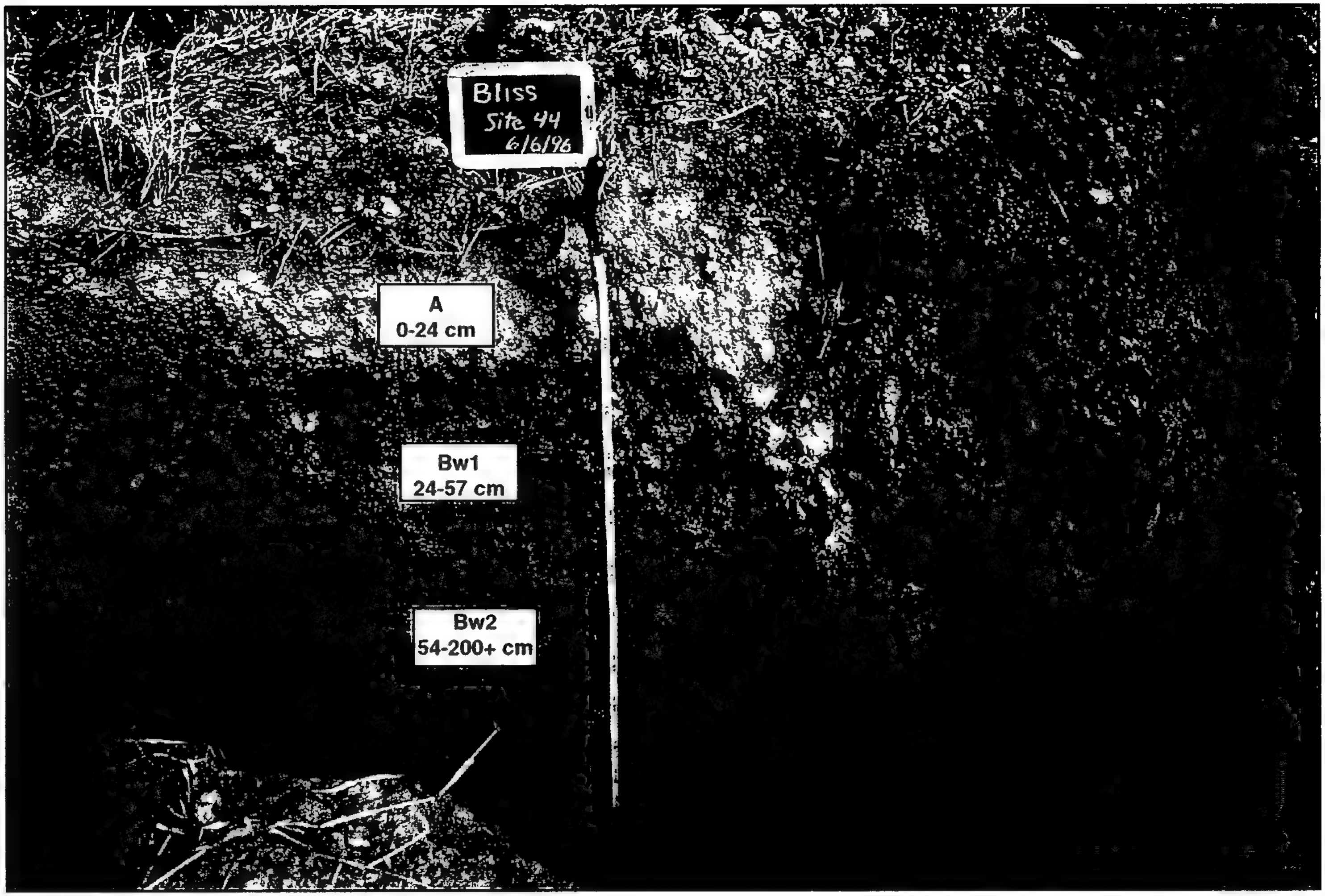


Figure 85. Lake Tank Playa, site 44, soil profile. Lake Tank playa lies in a north-south oriented mini-graben on the southeastern side of the Tularosa Basin. It is the base level to which many alluvial fans and intermittent streams in this limestone terrain drain. These sediments contain abundant well preserved pollen, samples of which from 100-110 cm and 180-190 cm depths gave AMS (accelerator) radiocarbon ages of 2,730±60 and 5,280±60 ryBP (see Table 1). The dates indicate that the late Quaternary human and prehuman environment of this area can be reconstructed and dated at high levels of resolution; and that the reconstruction would be independent (and augment) those based on pack rat midden analyses recently done in the Hueco Mountains.

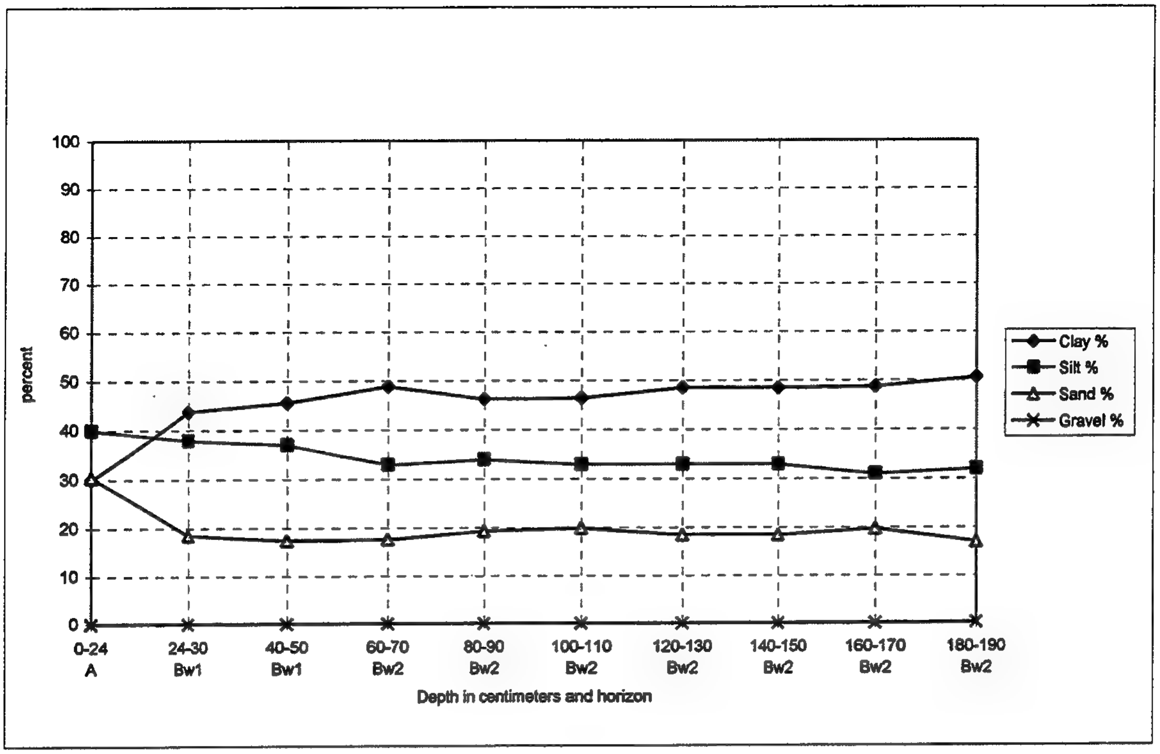
Table 13
Lake Tank, Site 44, McGregor Range, New Mexico
Particle Size and Chemical Data

Particle Size Data

		Sediment / Percent											
Horizon	Depth	Clay	Silt	Sand	Fine Silt	Coarse Silt	Very Fine Sand	Fine Sand	Medium Sand	Coarse Sand	Very Coarse Sand	Gravel	Textural Class
A	0-24	30.00	40.00	30.50	24.70	14.90	20.30	7.90	0.40	0.50	1.40	0.00	CL
Bw1	24-30	43.80	38.00	18.60	25.70	11.90	12.20	5.30	0.30	0.30	0.60	0.00	C
Bw1	40-50	45.60	37.00	17.50	26.00	10.90	11.40	5.30	0.20	0.20	0.40	0.00	C
Bw2	60-70	48.90	33.00	17.70	22.50	10.90	11.60	5.60	0.20	0.10	0.20	0.00	C
Bw2	80-90	46.30	34.00	19.40	22.80	11.60	12.60	6.40	0.10	0.10	0.10	0.00	C
Bw2	100-110	46.50	33.00	20.00	22.90	10.50	13.10	6.40	0.20	0.20	0.20	0.00	C
Bw2	120-130	48.60	33.00	18.50	22.50	10.50	12.30	5.80	0.10	0.10	0.10	0.00	C
Bw2	140-150	48.50	33.00	18.50	21.70	11.30	12.40	5.70	0.10	0.10	0.10	0.00	C
Bw2	160-170	48.80	31.00	19.80	20.10	11.20	13.10	6.50	0.10	0.10	0.10	0.00	C
Bw2	180-190	50.70	32.00	17.10	21.60	10.60	11.10	5.60	0.20	0.00	0.10	0.20	C

Chemical Data

Horizon	Depth	Ca meq/100g	Mg meq/100g	Na meq/100g	K meg/100g	Sum of Bases meq/100g	Acidity meq/100g	Al meq/100g	CEC by sum of cations meq/100g	CEC-7 (NH4OAc) meq/100g	CEC Bases + Al	Al Sat %	Base Sat by sum %	Base Sat by CEC-7 %	Organic Carbon %	Salt pH .01M CaCl2	Water pH
A	0-24	54.10	2.80	0.10	2.30	59.30	0.00	--	59.30	23.30	--	--	100.00	100.00	1.50	7.70	7.90
Bw1	24-30	55.90	3.10	TR	1.90	60.90	0.00	--	60.90	23.60	--	--	100.00	100.00	1.00	7.70	8.00
Bw1	40-50	54.50	3.20	TR	1.30	59.00	0.00	--	59.00	22.00	--	--	100.00	100.00	0.70	7.70	8.00
Bw2	60-70	48.10	2.70	TR	2.30	53.10	0.00	--	53.10	22.90	--	--	100.00	100.00	0.60	7.70	8.10
Bw2	80-90	48.50	5.20	0.10	1.40	55.20	0.00	--	55.20	19.60	--	--	100.00	100.00	0.40	7.70	8.10
Bw2	100-110	47.90	6.00	TR	1.30	55.20	0.00	--	55.20	19.10	--	--	100.00	100.00	0.40	7.70	8.10
Bw2	120-130	46.30	6.50	TR	1.20	54.00	0.00	--	54.00	19.20	--	--	100.00	100.00	0.30	7.70	8.10
Bw2	140-150	47.10	6.70	0.10	1.20	55.10	0.00	--	55.10	19.10	--	--	100.00	100.00	0.30	7.80	8.10
Bw2	160-170	50.80	6.90	0.10	1.20	59.00	0.00	--	59.00	18.80	--	--	100.00	100.00	0.30	7.80	8.10
Bw2	180-190	50.40	6.90	0.10	1.20	58.60	0.00	--	58.60	19.10	--	--	100.00	100.00	0.30	7.80	8.20



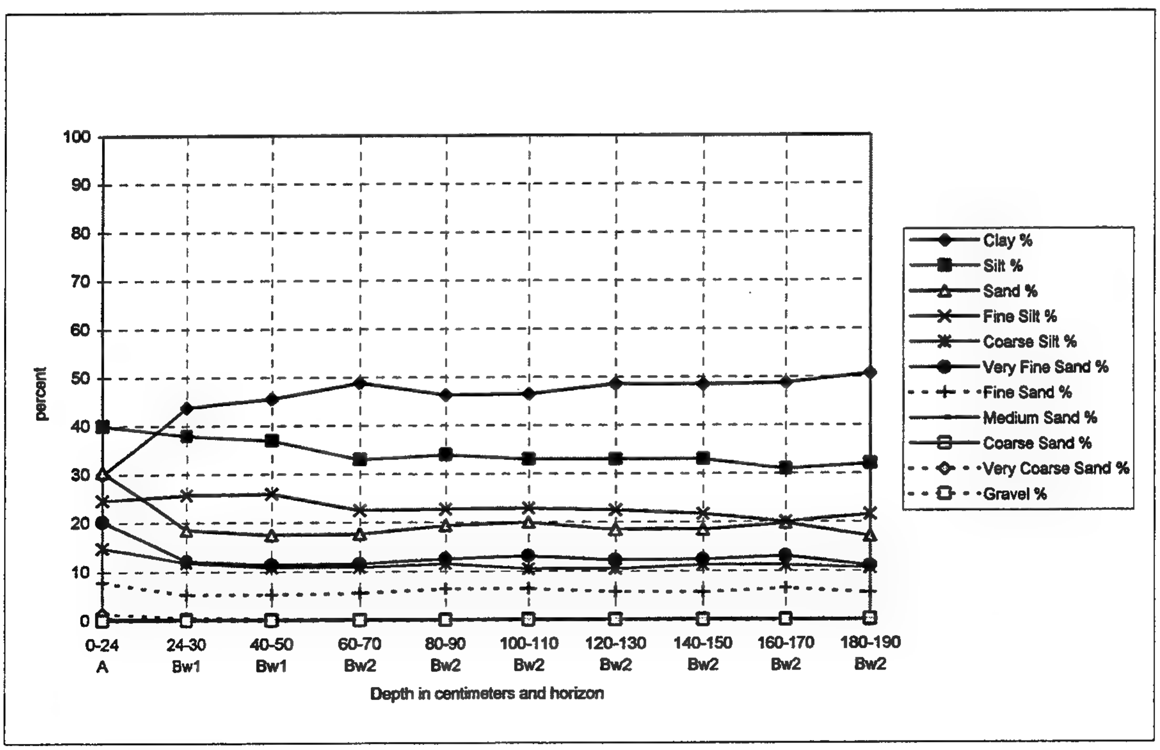


Figure 86. Lake Tank Playa, site 44, depth functions of four (upper) and 11 (lower) particle sizes (gravels were not present; data from Table 13).

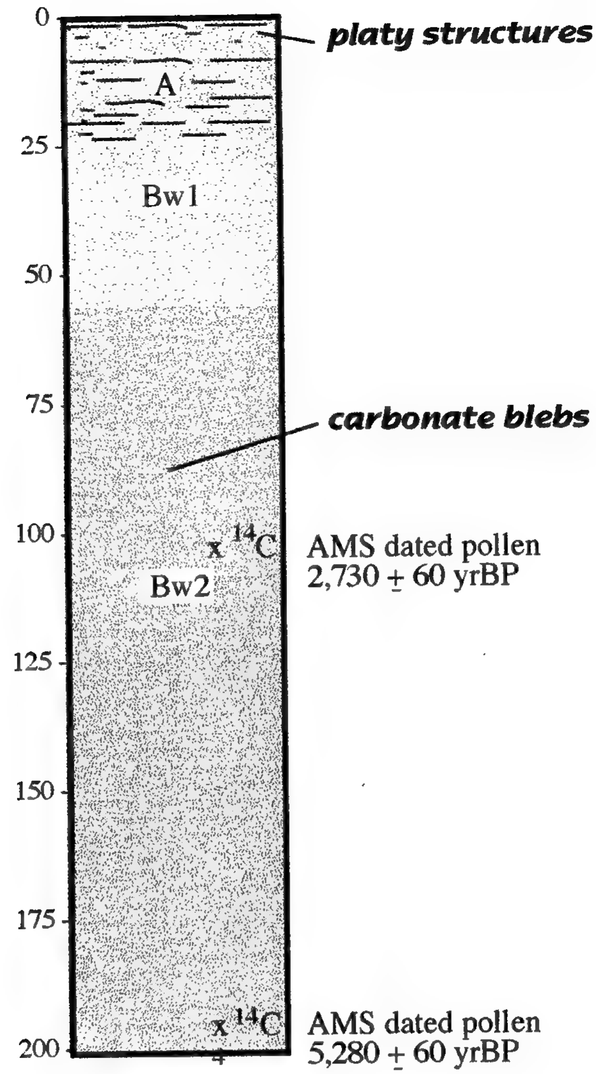


Figure 87. Profile schematic of site 44, Lake Tank Playa, McGregor Range, New Mexico.

The Pluton Pit pedons, and soils in the surrounding area, epitomize how soils in general evolve on McGregor (playas are the exception). Aside from the A1 horizon, which consists of frequently reformed surface wash stratifications (whenever it rains), the major vectors of soil evolution at this site are *biomechanical* and *biochemical* (Axiom 4). The biomechanical vector involves badgers and rodents (gophers, kangaroo rats, ground squirrels) on the one hand, and soil invertebrates (ants, termites, cicadas, etc.) on the other. The biochemical vector is biochemically precipitated calcium carbonate (caliche). That part of the profile to the top of the Bk1m horizon is the biomantle because it has been dominantly impacted (i.e., more or less destratified) by bioturbation—the biomechanical vector. The Bk1m horizon is largely stratified, though some destratification has occurred. The latter horizon, however, is dominated by biochemically precipitated caliche—the biochemical vector.

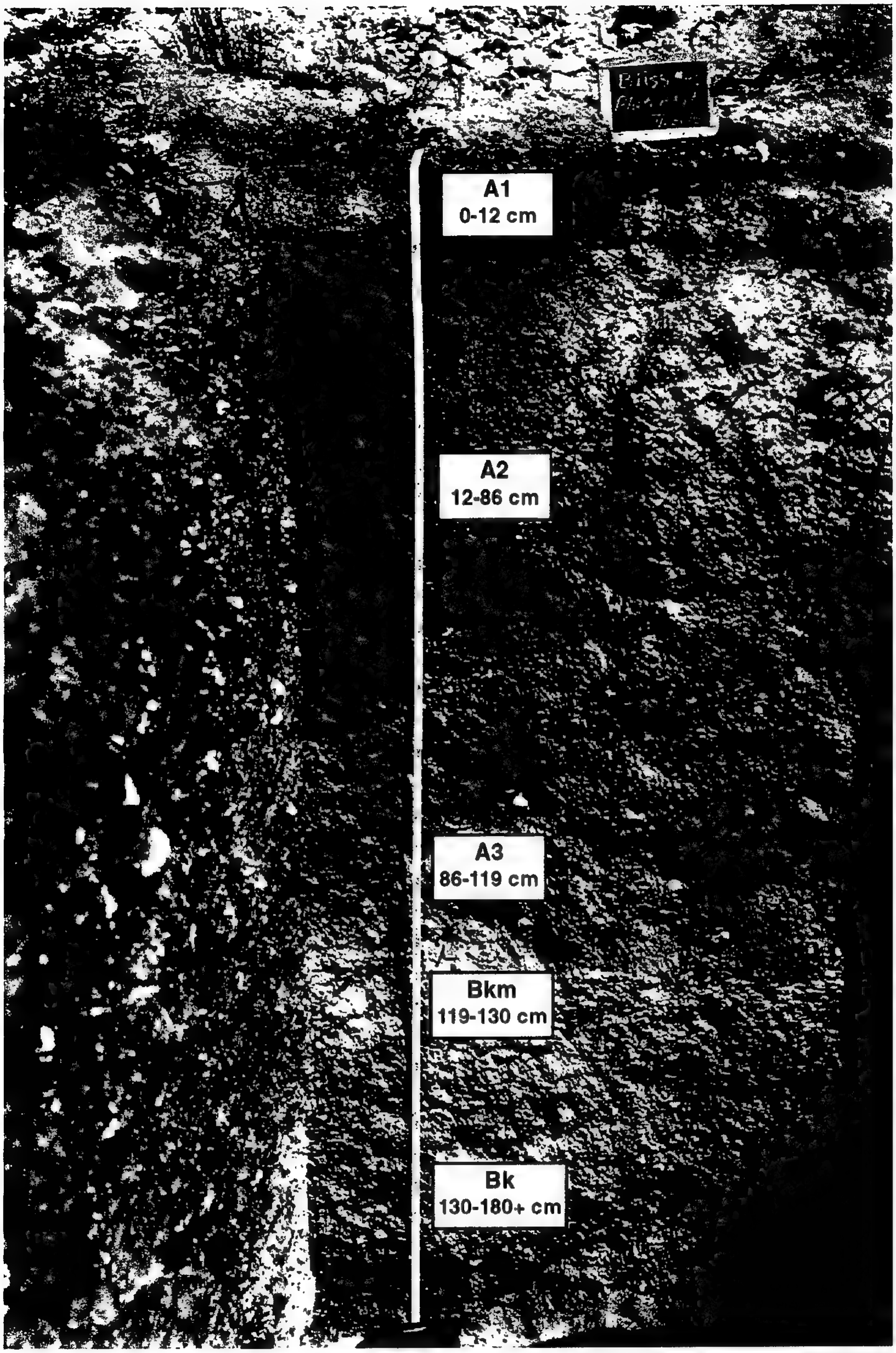


Figure 88. Pluton Pit, site 46, soil profile. This roadside site is several kilometers southwest of Lake Tank in a saddle between two limestone hills, one of which contains an igneous intrusion (pluton). Two pedons were described: one (this photo) to the pit floor at 190 cm, the other to the top of the petrocalcic (Bkm) horizon. Gravels in the Bkm are of mixed sizes, more or less stratified, and cemented by laminar caliche. This horizon is strongly bioturbated by insects, with abundant vertical, cicada-like burrow infillings. The destratified biomantle (to the top of the Bkm horizon) ranges from 101 to 122 cm depth.

Table 14
Pluton, Site 46, McGregor Range, New Mexico
Particle Size and Chemical Data

Particle Size Data Pedon 1

Horizon	Depth	Sediment / Percent: Clay	Silt	Sand	Fine Silt	Coarse Silt	Very Fine Sand	Fine Sand	Medium Sand	Coarse Sand	Very Coarse Sand	Gravel	Textural Class
A1	0-12	3.40	6.70	89.90	1.80	4.90	27.90	60.50	1.00	0.30	0.20	0.00	FS
A2	12-20	5.00	5.80	89.20	1.60	4.20	20.70	55.30	8.80	3.90	0.50	5.10	FS
A2	20-30	5.10	5.80	89.10	1.20	4.60	20.60	57.10	7.60	3.50	0.40	3.40	FS
A2	30-40	5.20	6.40	88.50	1.20	5.20	20.00	56.20	8.60	3.30	0.40	4.70	FS
A2	40-50	4.80	6.80	88.50	1.20	5.60	20.00	58.10	7.00	3.00	0.40	2.90	FS
A2	50-60	5.00	6.30	88.70	1.20	5.10	20.40	57.50	7.70	2.80	0.20	2.00	FS
A2	60-70	5.40	6.00	88.60	0.90	5.10	19.20	59.70	6.60	2.80	0.30	4.30	FS
A2	70-86	5.60	6.70	87.70	1.50	5.30	20.10	57.40	7.20	2.70	0.40	3.60	LFS
A3	86-100	6.80	9.60	83.70	2.40	7.20	22.40	51.40	5.70	3.20	0.90	22.30	LFS
A3	100-110	8.20	10.40	81.40	2.50	7.90	23.80	46.70	6.10	3.70	1.10	23.60	LFS
A3	110-119	8.50	11.60	79.90	2.60	9.00	23.40	46.60	5.00	3.50	1.40	38.60	LFS
Bk1m	119-130	10.30	9.50	80.20	2.20	7.30	23.20	43.80	6.50	4.70	2.00	5.70	FSL
Bk2	130-140	10.60	9.00	80.40	3.00	5.90	23.20	43.50	6.00	5.10	2.70	26.20	FSL
Bk2	140-150	11.60	9.50	78.90	2.80	6.70	23.00	41.70	7.20	5.60	1.40	21.10	FSL
Bk2	150-160	11.40	9.70	78.90	2.90	6.80	23.40	42.50	6.10	5.30	1.60	20.60	FSL

Particle Size Data Pedon 2

Horizon	Depth	Sediment / Percent: Clay	Silt	Sand	Fine Silt	Coarse Silt	Very Fine Sand	Fine Sand	Medium Sand	Coarse Sand	Very Coarse Sand	Gravel	Textural Class
A1	0-14	4.90	5.40	89.80	0.70	4.70	22.80	58.40	5.90	2.40	0.30	4.40	FS
A2	14-20	5.00	4.60	90.40	0.90	3.70	18.60	58.60	8.50	4.20	0.50	5.50	FS
A2	20-30	4.80	6.70	88.60	1.10	5.50	18.60	56.60	9.30	3.70	0.40	4.30	FS
A2	30-40	5.00	5.40	89.60	1.40	4.00	20.50	58.40	7.30	3.10	0.30	4.70	FS
A2	40-50	5.10	5.30	89.60	0.70	4.60	19.20	57.90	8.90	3.30	0.20	9.60	FS
A2	50-60	4.60	6.20	89.20	0.90	5.20	18.20	60.20	7.40	3.10	0.30	2.30	FS
A2	60-70	5.10	5.40	89.50	0.90	4.50	18.30	59.40	8.60	2.90	0.30	3.00	FS
A2	70-80	5.00	5.00	90.00	0.70	4.30	18.70	61.10	7.30	2.80	0.10	3.10	FS
A2	80-90	5.70	6.60	87.70	1.00	5.60	19.60	56.80	7.90	3.00	0.40	14.20	LFS
A2	90-99	6.80	8.20	85.00	1.80	6.40	21.30	53.90	6.10	3.10	0.60	18.00	LFS

Table 14 (cont'd)

Horizon	Depth	Clay	Silt	Sand	Fine Silt	Coarse Silt	Very Fine Sand	Fine Sand	Medium Sand	Coarse Sand	Very Coarse Sand	Gravel	Textural Class
		Sediment / Percent											
Bk1m	99-110	6.90	8.90	84.20	2.30	6.60	21.60	51.70	6.60	3.50	0.80	18.30	LFS
Bk2	110-120	7.90	10.60	81.50	2.70	7.90	23.20	47.60	5.50	3.60	1.50	39.80	LFS

Chemical Data Pedon 1

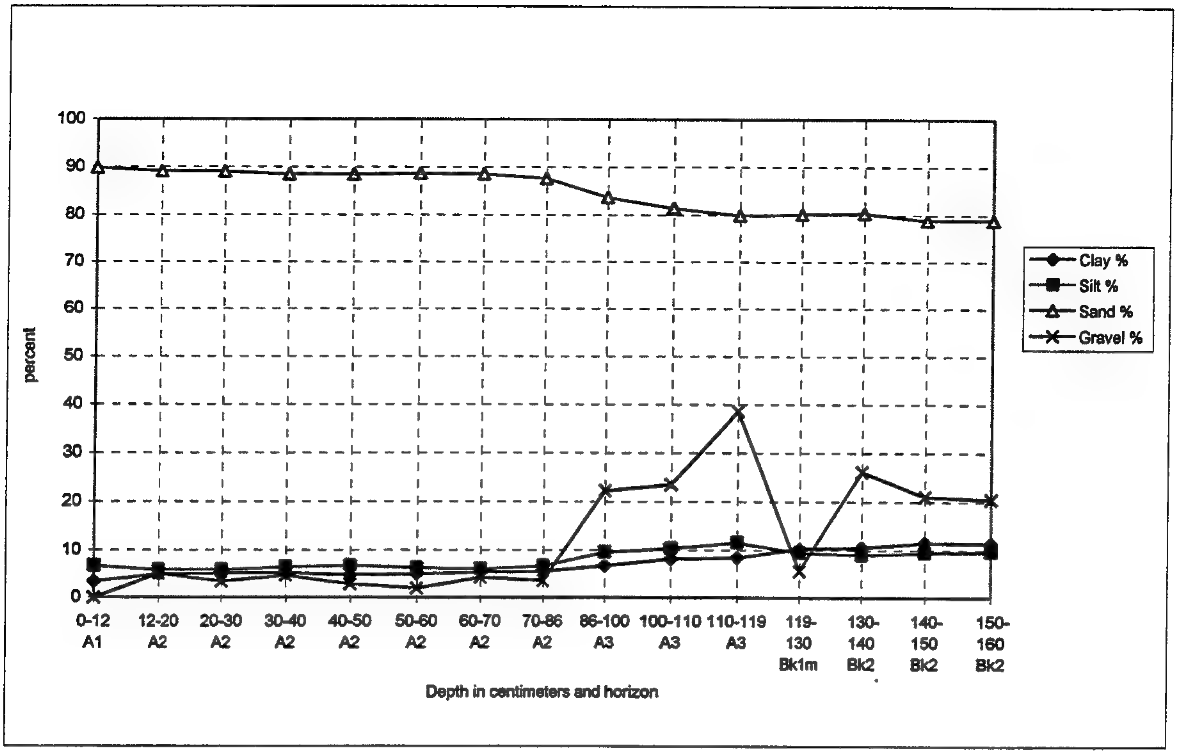
Horizon	Depth	Ca meq/100g	Mg meq/100g	Na meq/100g	K meg/100g	Sum of Bases meq/100g	Acidity meq/100g	Al meq/100g	CEC by sum of cations meq/100g	CEC-7 (NH4OAc) meq/100g	CEC Bases + Al	Al Sat %	Base Sat by sum %	Base Sat by CEC-7 %	Organic Carbon %	Salt pH .01M CaCl2	Water pH
A1	0-12	40.30	1.20	TR	0.40	41.90	0.00	--	41.90	6.20	--	--	100.00	100.00	0.20	6.90	7.80
A2	12-20	37.90	0.80	0.00	0.30	39.00	0.00	--	39.00	5.60	--	--	100.00	100.00	0.20	7.30	8.00
A2	20-30	39.70	0.80	TR	0.20	40.70	0.00	--	40.70	5.30	--	--	100.00	100.00	0.20	7.30	8.00
A2	30-40	38.50	0.80	TR	0.20	39.50	0.00	--	39.50	5.30	--	--	100.00	100.00	0.20	7.30	8.00
A2	40-50	39.00	0.80	0.00	0.20	40.00	0.00	--	40.00	4.90	--	--	100.00	100.00	0.10	7.30	8.10
A2	50-60	40.50	0.80	0.00	0.20	41.50	0.00	--	41.50	5.00	--	--	100.00	100.00	0.10	7.30	8.10
A2	60-70	39.60	0.80	0.00	0.20	40.60	0.00	--	40.60	4.90	--	--	100.00	100.00	0.10	7.40	8.10
A2	70-86	41.50	0.80	0.00	0.20	42.50	0.00	--	42.50	5.00	--	--	100.00	100.00	0.10	7.40	8.20
A3	86-100	47.50	1.20	0.00	0.20	48.90	0.00	--	48.90	5.60	--	--	100.00	100.00	0.10	7.50	8.20
A3	100-110	41.50	1.20	TR	0.30	43.00	0.00	--	43.00	5.60	--	--	100.00	100.00	0.20	7.50	8.10
A3	110-119	40.40	1.20	TR	0.20	41.80	0.00	--	41.80	5.60	--	--	100.00	100.00	0.20	7.50	8.20
Bk1m	119-130	42.90	1.60	TR	0.20	44.70	0.00	--	44.70	5.70	--	--	100.00	100.00	0.20	7.60	8.10
Bk2	130-140	44.10	1.70	TR	0.20	46.00	0.00	--	46.00	5.90	--	--	100.00	100.00	0.20	7.60	8.20
Bk2	140-150	42.90	2.00	0.10	0.20	45.20	0.00	--	45.20	6.70	--	--	100.00	100.00	0.20	7.60	8.20
Bk2	150-160	43.90	2.00	0.20	0.20	46.30	0.00	--	46.30	7.00	--	--	100.00	100.00	0.10	7.60	8.20

Chemical Data Pedon 2

Horizon	Depth	Ca meq/100g	Mg meq/100g	Na meq/100g	K meg/100g	Sum of Bases meq/100g	Acidity meq/100g	Al meq/100g	CEC by sum of cations meq/100g	CEC-7 (NH4OAc) meq/100g	CEC Bases + Al	Al Sat %	Base Sat by sum %	Base Sat by CEC-7 %	Organic Carbon %	Salt pH .01M CaCl2	Water pH
A1	0-14	35.50	0.80	TR	0.50	36.80	0.00	--	36.80	5.60	--	--	100.00	100.00	0.20	7.50	8.10
A2	14-20	35.50	0.80	0.10	0.30	36.70	0.00	--	36.70	4.80	--	--	100.00	100.00	0.20	7.50	8.10
A2	20-30	39.30	0.80	TR	0.30	40.40	0.00	--	40.40	5.10	--	--	100.00	100.00	0.20	7.50	8.10
A2	30-40	38.30	0.80	TR	0.30	39.40	0.00	--	39.40	5.30	--	--	100.00	100.00	0.20	7.50	8.10
A2	40-50	36.90	0.80	TR	0.20	37.90	0.00	--	37.90	4.80	--	--	100.00	100.00	0.20	7.50	8.10
A2	50-60	37.90	0.80	TR	0.20	38.90	0.00	--	38.90	4.70	--	--	100.00	100.00	0.10	7.50	8.10
A2	60-70	39.80	0.80	TR	0.20	40.80	0.00	--	40.80	4.60	--	--	100.00	100.00	0.10	7.50	8.10

Table 14 (cont'd)

Horizon	Depth	Ca meq/100g	Mg meq/100g	Na meq/100g	K meg/100g	Sum of Bases meq/100g	Acidity meq/100g	Al meq/ 100g	CEC by sum of cations meq/100g	CEC-7 (NH4OAc) meq/100g	CEC Bases + Al	Al Sat %	Base Sat by sum %	Base Sat by CEC-7 %	Organic Carbon %	Salt pH .01M CaCl2	Water pH
A2	70-80	36.20	1.20	TR	0.20	37.60	0.00	--	37.60	4.50	--	--	100.00	100.00	0.10	7.50	8.10
A2	80-90	38.30	1.20	0.10	0.20	39.80	0.00	--	39.80	4.70	--	--	100.00	100.00	0.10	7.50	8.10
A2	90-99	39.20	1.20	0.10	0.20	40.70	0.00	--	40.70	5.30	--	--	100.00	100.00	0.10	7.50	8.10
Bklm	99-110	38.50	1.20	0.10	0.20	40.00	0.00	--	40.00	5.60	--	--	100.00	100.00	0.10	7.50	8.10
Bk2	110-120	40.50	1.60	0.20	0.20	42.50	0.00	--	42.50	5.70	--	--	100.00	100.00	0.10	7.60	8.20



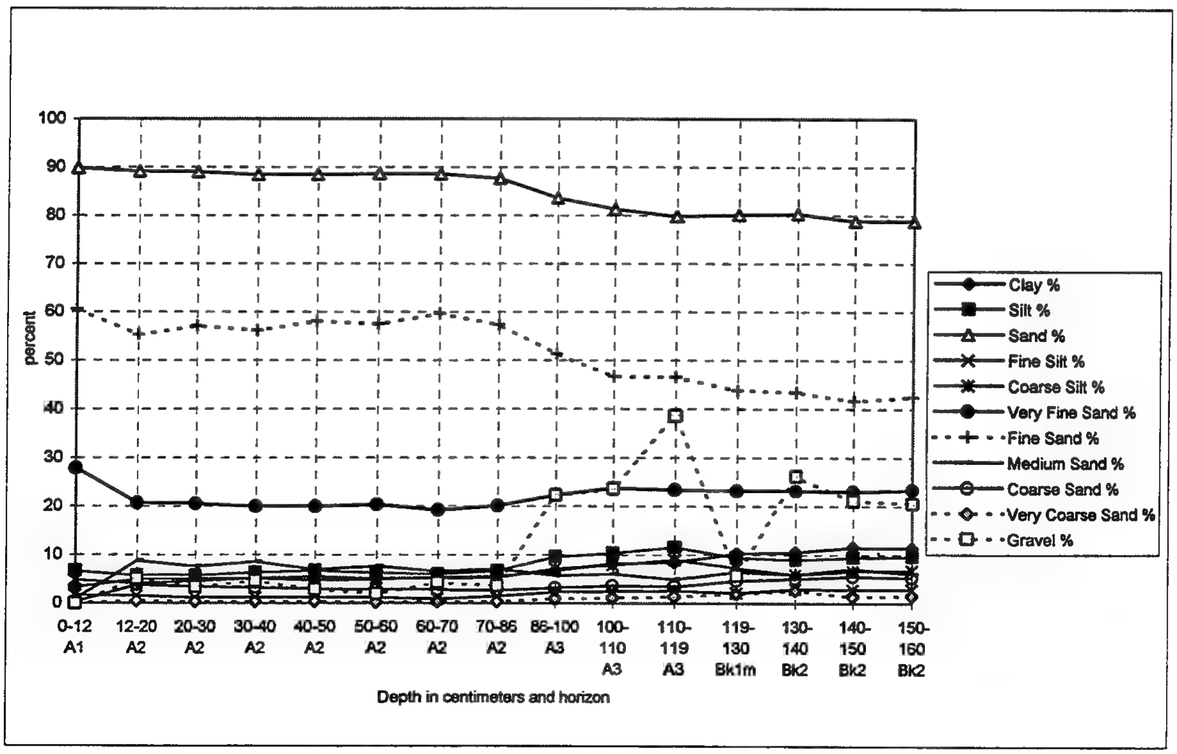
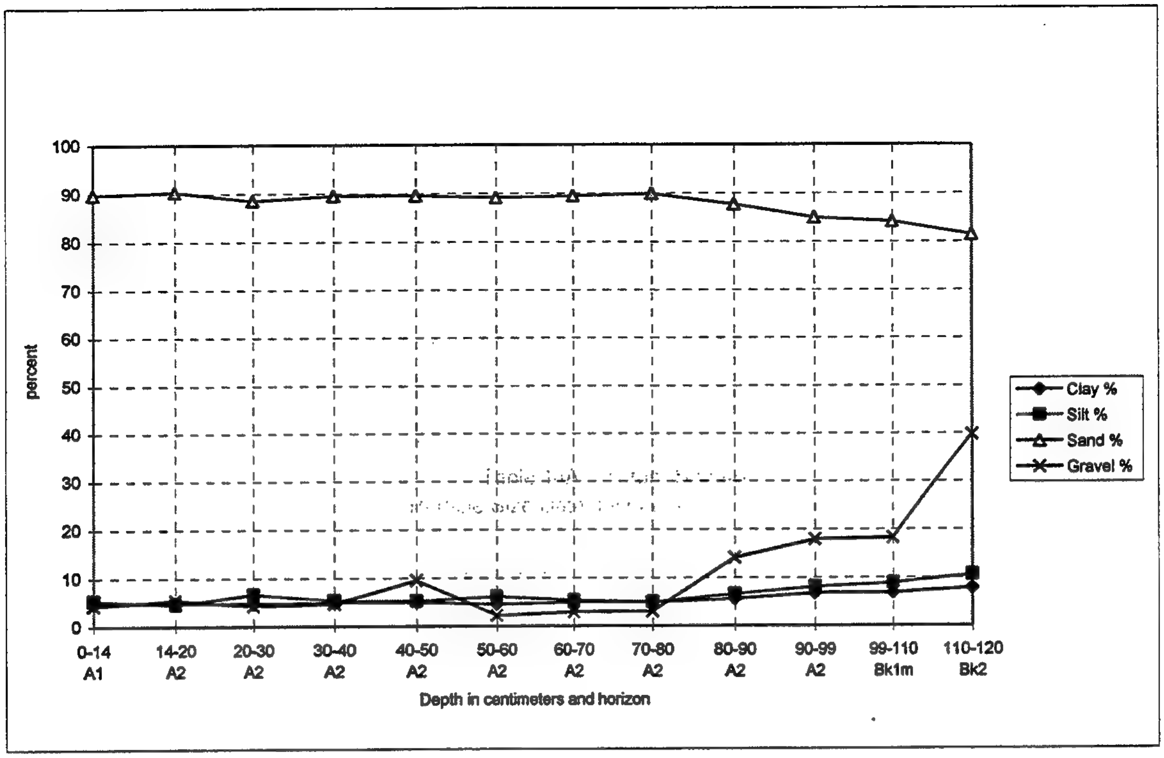


Figure 89. Pluton Pit, site 46, pedon 1, depth functions of four (upper) and 11 (lower) particle sizes (data from Table 14).



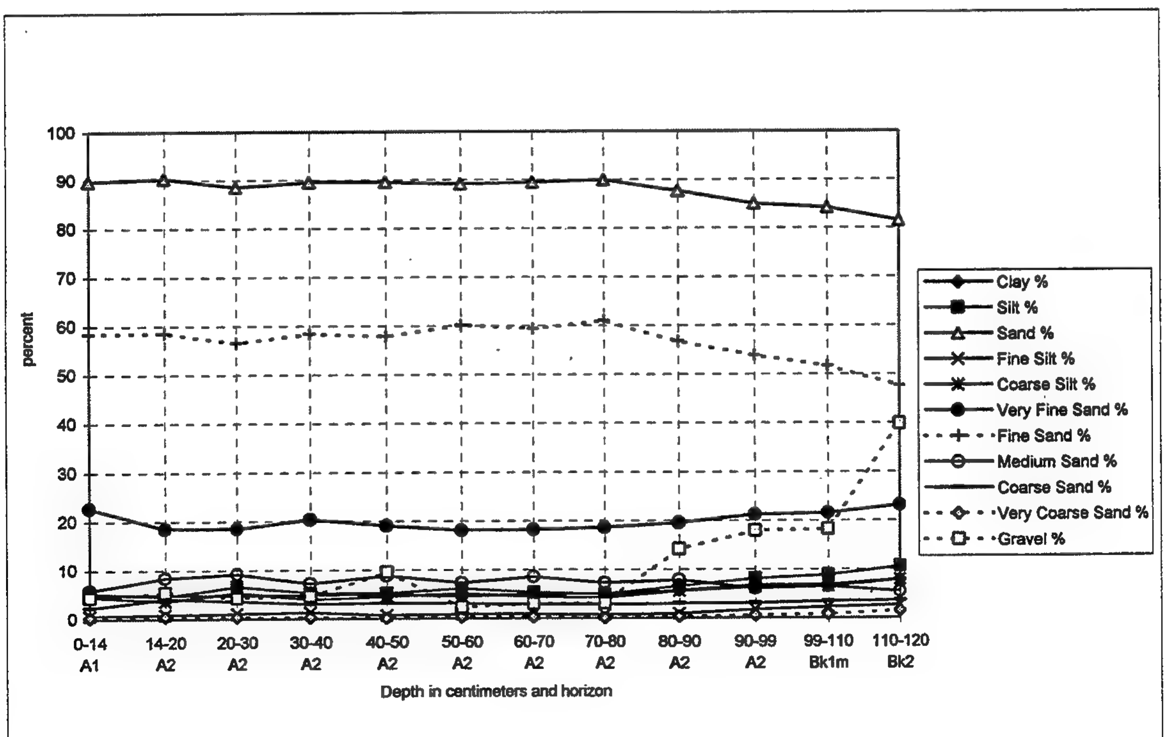
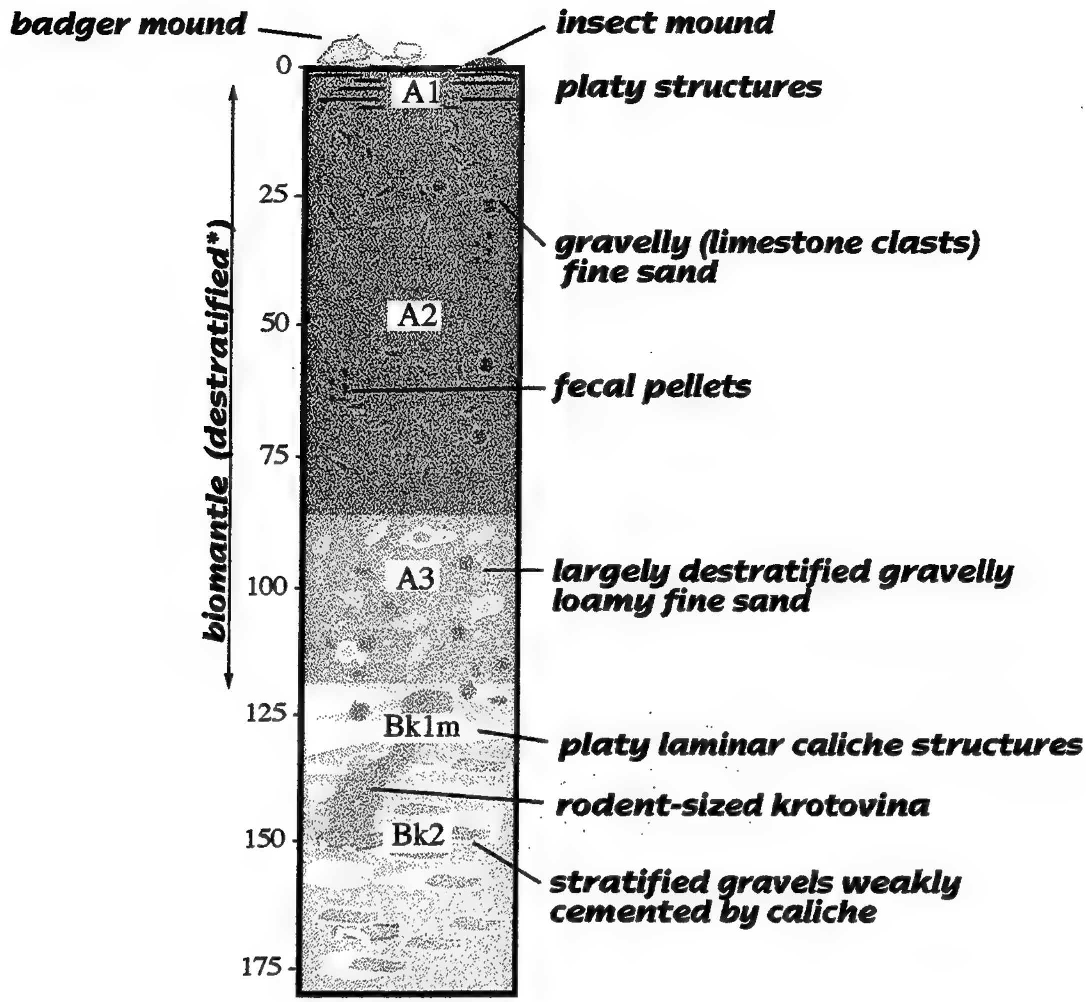


Figure 90. Pluton Pit, site 46, pedon 2, depth functions of particle sizes: (upper) four and (lower) 11 (data from Table 14).



* A1, A3, Bk1m, and Bk2 are undergoing destratification

Figure 91. Profile schematic of pedon 1 at site 46, Pluton Pit, McGregor Range, New Mexico.

As slope changes a third vector comes into play, the physical processes of erosion and deposition (cf., Axiom 3). Figures 92-95, all taken immediately south of Pluton Pit, demonstrate graphically how these three vectors intimately interplay to produce many of the sediment-soil landscapes of McGregor.

3. *Stone School, site 42.* This site is about nine miles (14.48 km) east of the McGregor Range Camp, some 30 m north of the main road that runs between Flat Tank and School Tank, and is about 250 ± m north of the old stone schoolhouse identified on the Desert SE quad as 'Ruins.' It is on a relict fan segment in the midsection of a broad alluvial draw composed of limestone-derived gravelly alluvium (the Stone School segment is an A2 mapping unit, Desert SE quad). Like Pluton Pit, surface evidence of small vertebrate bioturbation, mainly by gophers and badgers, is unmistakable with abundant mounds and burrows of these animals seemingly everywhere, most with associated upchurned calichified stones obviously brought up from some depth. In fact, it was the excessive burrowing of the calcic and petrocalcic horizon on this surface and others like it, similar to that at Pluton Pit (Site 42), Dust Pit (Site 40), Sulphur (Site 1), and near Camaleche

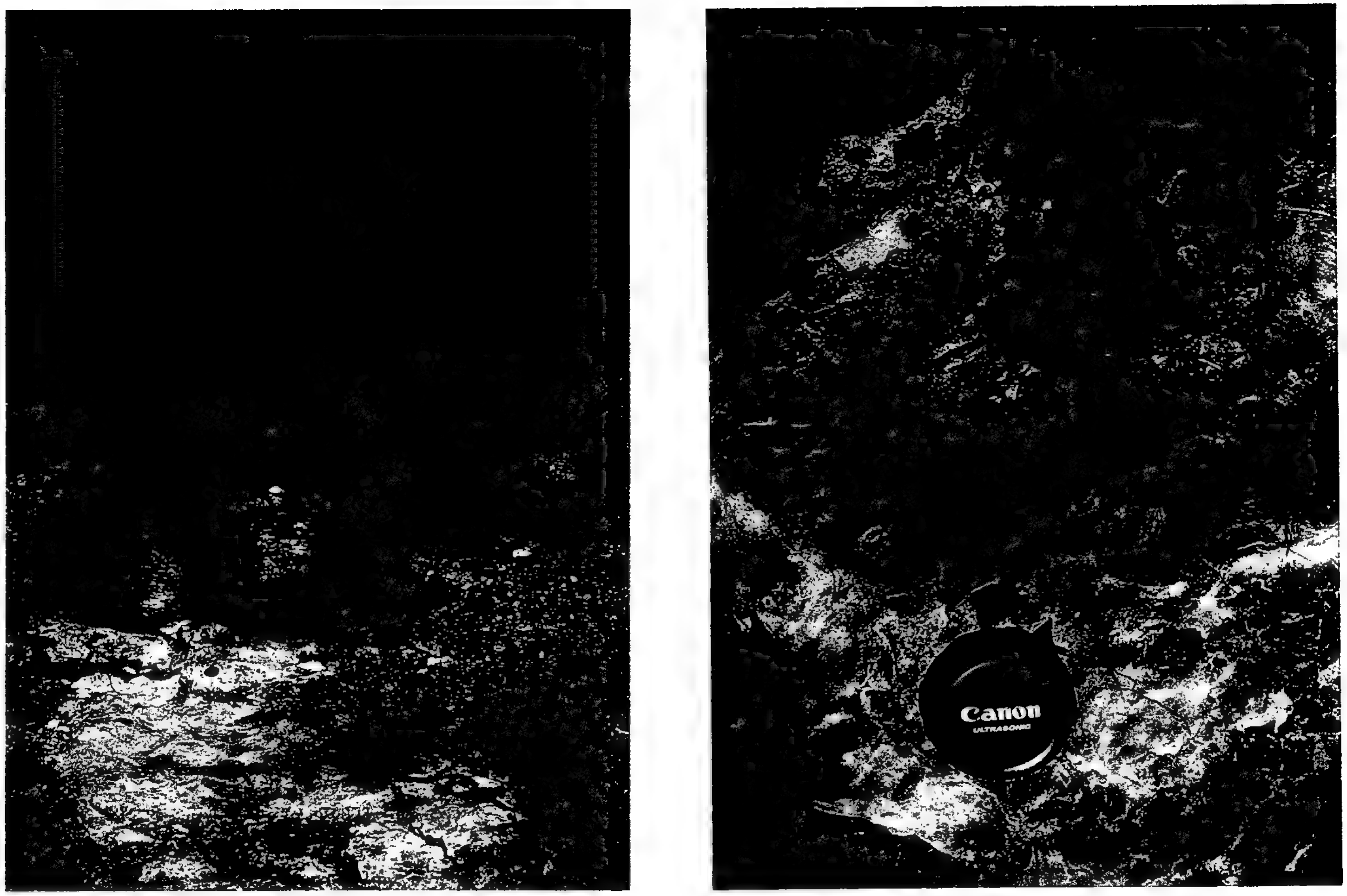


Figure 92. Two views of the area just south and upslope from Pluton Pit, site 46, that show the role of slope, biochemical, and biomechanical factors in affecting sediment-soil thickness. Left photo shows petrocalcic caliche in a slight swale with a thin veneer of topsoil, and no topsoil in places. The mass of rock in the middle background is the syenite pluton after which Pluton Pit is named. The light area behind the pluton is caused by many fresh gopher mounds that had been produced in the weeks and months previous to when the photo was taken (close-up views of them are in Figure 93). The right photo is a closeup of the surface of the petrocalcic horizon, showing embedded limestone fragments cemented in place by mainly laterally flowing surface and, formerly, subsurface meteoric waters.

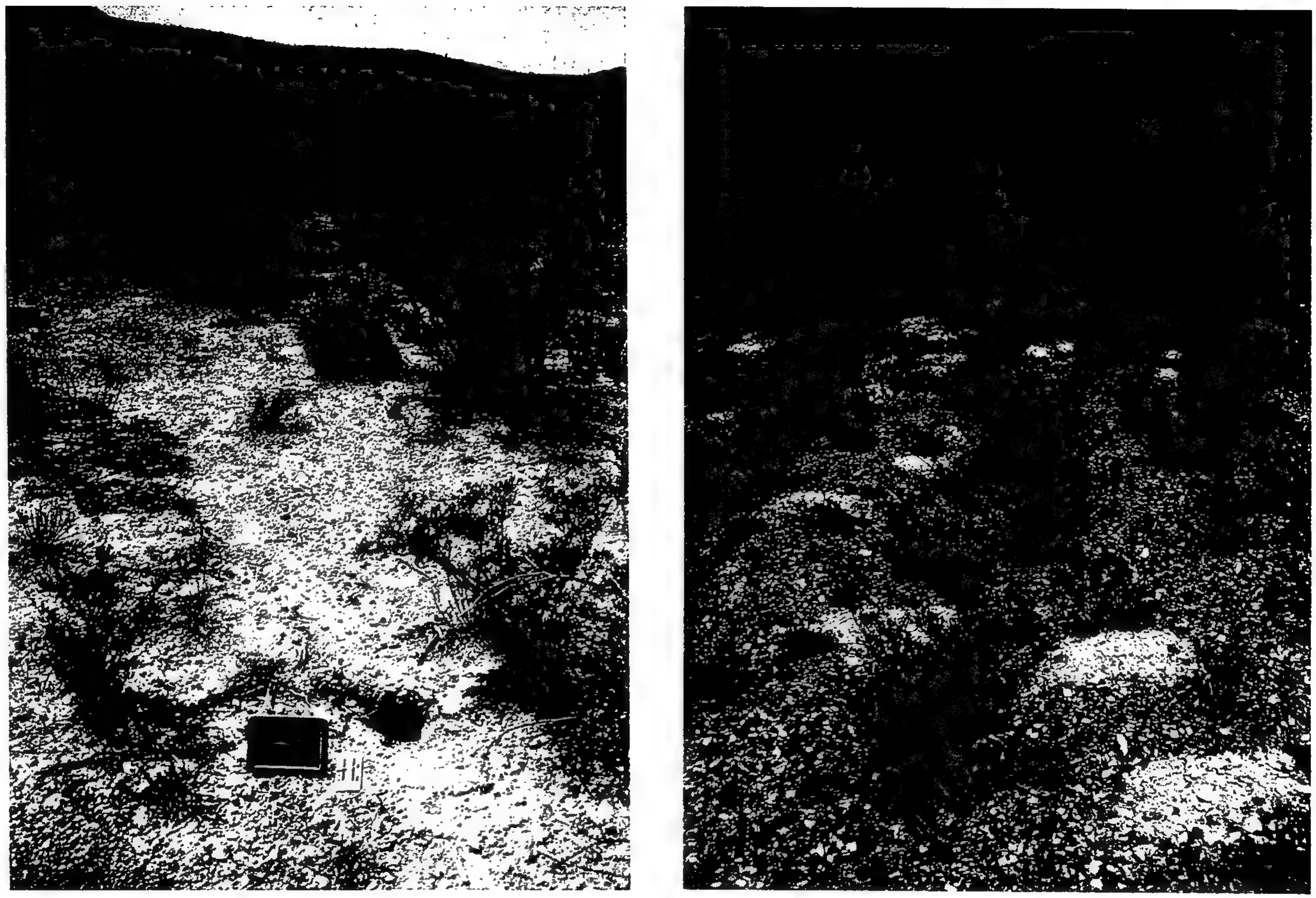


Figure 93. Two more views of the area around the igneous pluton near Pluton Pit, site 46 (cf., Figure 92). The left photo shows many fresh gopher mounds that will be subject to easy erosion when rains fall. This moundfield is seen as a light colored area from a distance in Figure 92. The right photo shows a nearby badger mound and burrow, one of many in the area. The biomechanical role of animals on McGregor sediments and soils is a key element in the landscape evolution of the base.

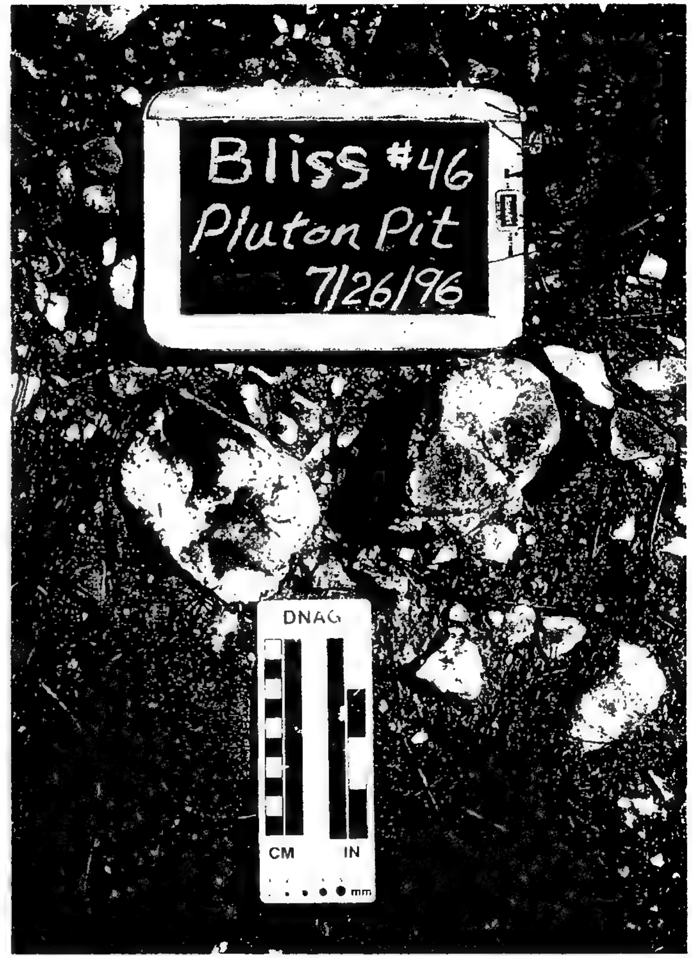


Figure 94. More views on the roles of vertebrate bioturbators on McGregor (cf., Figures 92 and 93). In the left photo, almost all surface exposed gravels have been brought up from the subsurface by fossorial vertebrates, here mainly rodents, and of those, mainly gophers. In the right photo are larger caliche-coated clasts that are associated with a wasted badger mound and burrow.

Figure 95. Views of invertebrate bioturbation of fine fraction, by ants in the upper photo and by an unknown animal in the lower photo. Ants are ubiquitous on the McGregor landscape, and although the writer could not quantify their role in contributing fine fraction to the biomantle, it collectively must be a significant and underappreciated one.

Tanks on Otero Mesa, that discouraged our original plan to map the geomorphic surfaces of McGregor using soil development—mainly calcic-petrocalcic development—as age indicators. The full description of a backhoe pit pedon is in Appendix D, a view of the profile is in Figure 96, laboratory data are in Table 15, and depth function graphs of particle size are in Figure 97. Figure 98 is a profile schematic drawn from these data.

These data show that a biomantle comprises the upper meter or so of the profile (based on 11 measurements from the surface down to the top of the Bk horizon; see Remarks in sediment-soil description). Bioturbation of this relict A2 alluvial segment has destratified the originally stratified gravels and has produced the ~1 m thick biomantle. Bioturbation is clearly the dominant pedogenic vector in the upper and middle profile. The biochemical vector is dominant in the Bk and CBk horizons.

Badgers and gophers in particular have strongly impacted the upper meter of the site. To gain a measure of the density and impact that badger burrowing alone can impart to a site, and to shed light on the pedological, geoecological, geomorphological, and geoarcheological implications of these processes for the McGregor Range and for the Chihuahuan desert generally, all visible old (wasted) and new (fresh) badger burrows and their associated mounds[7] were systematically counted, flagged, and numbered outward from the backhoe pit until 100 were counted. The burrows covered an area 159-x-83 m, or 13,197 m^2. The long axis of the largest stone from each of the 100 mounds was then measured, with resulting values that ranged from 4 cm (1.6 in) on mound number 11 to 29.2 cm (11.5 in) on mound number 33 (Table 16). The weight of the largest stone dug up by badgers, whose long axis measured 29.2 cm from mound number 33, was 5.5 kg (12.1 lbs). Figure 99 illustrates the role of badgers alone in the bioturbation processes in the area. Figure 100 provides graphic evidence of the role of gophers, largely apart from badgers, in creating two-layered biomantles (i.e., faunalmantles) in the area consisting of a gravelly loamy layer above a coarse clast stone-zone (see Johnson 1989, 1990 for a discussion of the processes).[8] Figure 101 shows the collective role of badgers and rodents in impacting the Stone School area.

4. *Dust Pit, site 40.* This site is at the upper midslope of the southwest-facing alluvial apron that fronts Borrego Ridge, between this ridge and the Alvarado Tank-Borrego Tank Road. It is about 20 m off the right (southeast) side of the diagonal road between Borrego Ridge and McGregor Range Camp (Borrego Ridge Road), and is on the A2-A3 mapping unit (Desert NE quad). It was named for the thick, billowing calcareous dust clouds that follow vehicles that use the road. The ground surface here, and the profiles exposed in the backhoe pit, attest to abundant bioturbation of the upper profile, which has produced a biomantle in the upper 70 cm or so.

One pedon was described in the backhoe pit, and horizon boundaries were delimited in two other pedons (see Remarks in sediment-soil description, Appendix D). Figures 102 and 103 show the described pedon and a second whose horizons were delimited. Laboratory data are in Table 17, depth functions of particle size are shown in Figure 104, and a profile schematic is shown in Figure 105.

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[7] Badger burrows and mounds ranged widely in character, from fresh ones with preserved badger claw marks on burrow entrances to those where burrows were almost completely infilled with associated mounds flattened by erosion and wasting. In extreme cases of the latter, only a patch or scatter of caliche-incrusted gravels remains as evidence for former burrowing.

[8] Badgers bioturbate fines, pebbles, and small cobble-sized caliche-coated clasts and caliche chunks, whereas gophers, ground squirrels, and kangaroo rats bioturbate only small clasts and fines. The collective burrowing activity of rodents, whose role probably surpasses that of badgers, causes large clasts that were bioturbated up by badgers to be displaced downward to form a stone-zone towards the base of the shallower rodent-bioturbated zone.

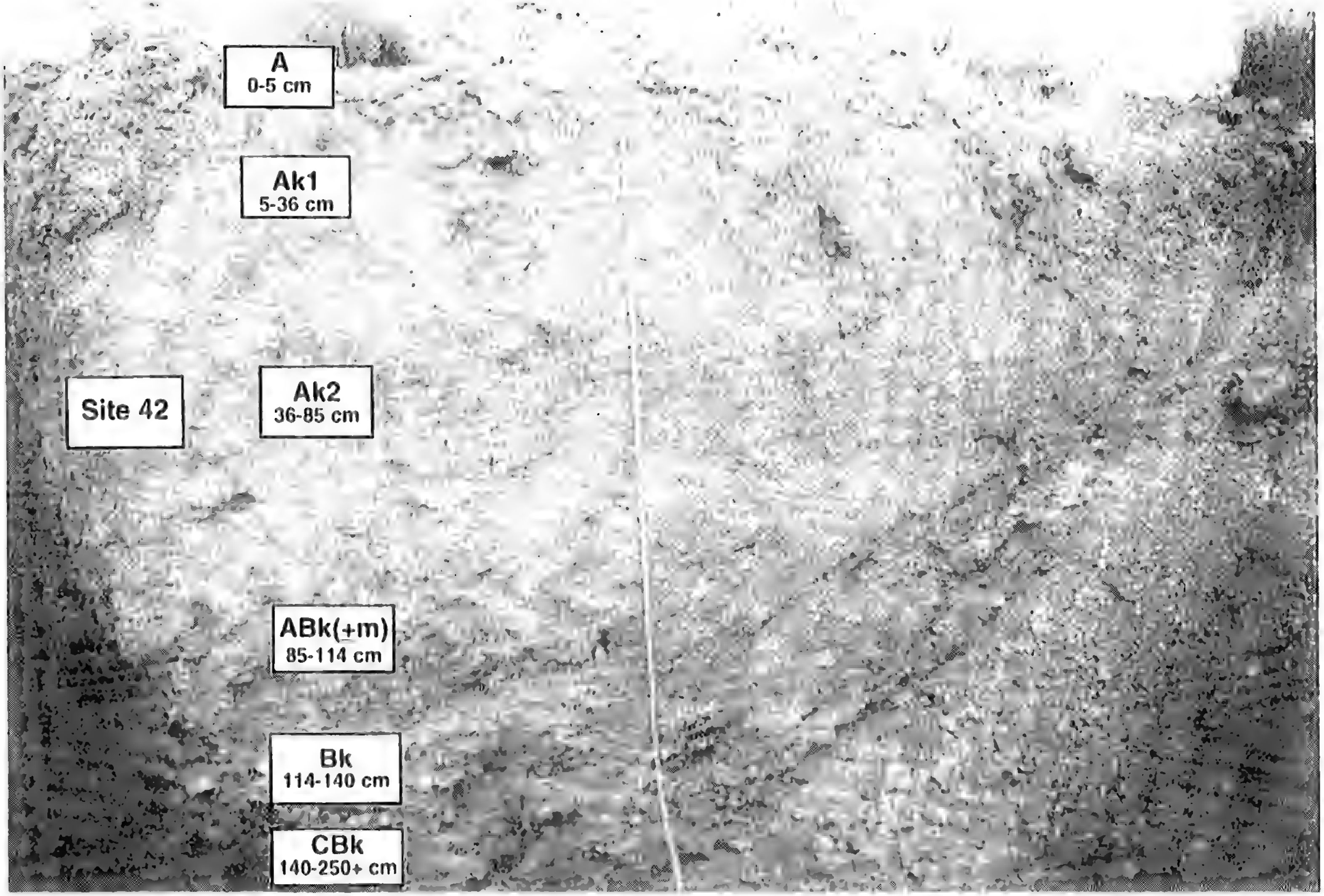


Figure 96. Stone School, site 42, sediments. This site is in the midsection of a large alluvial valley train fan in a bedrock bordered valley that heads in limestone rocks of the Hueco Mountains and Otero Escarpment. The fan surface exhibits abundant though sporadic gopher and badger mounds, where the latter almost always contain caliche coated clasts. The fan sediments here are destratified through the ABk(+m) horizon, a zone which collectively constitutes the biomantle. Its interface with the subjacent stratified gravels of the Bk horizon is wavy, varying from 86 to 145 cm depth. To gain a measure of the spatial bioturbational role of badgers, the closest 100 burrows to the backhoe pit—fresh, old, and very old ones—were systematically counted, flagged, and numbered, which defined an area of 159 x 83 m (1.32 ha). The largest stone collected from each ranged from 4 cm (1.6 in) to 29.2 cm (11.5 in), the latter (the heaviest) weighing 5.5 kg (12.1 lbs).

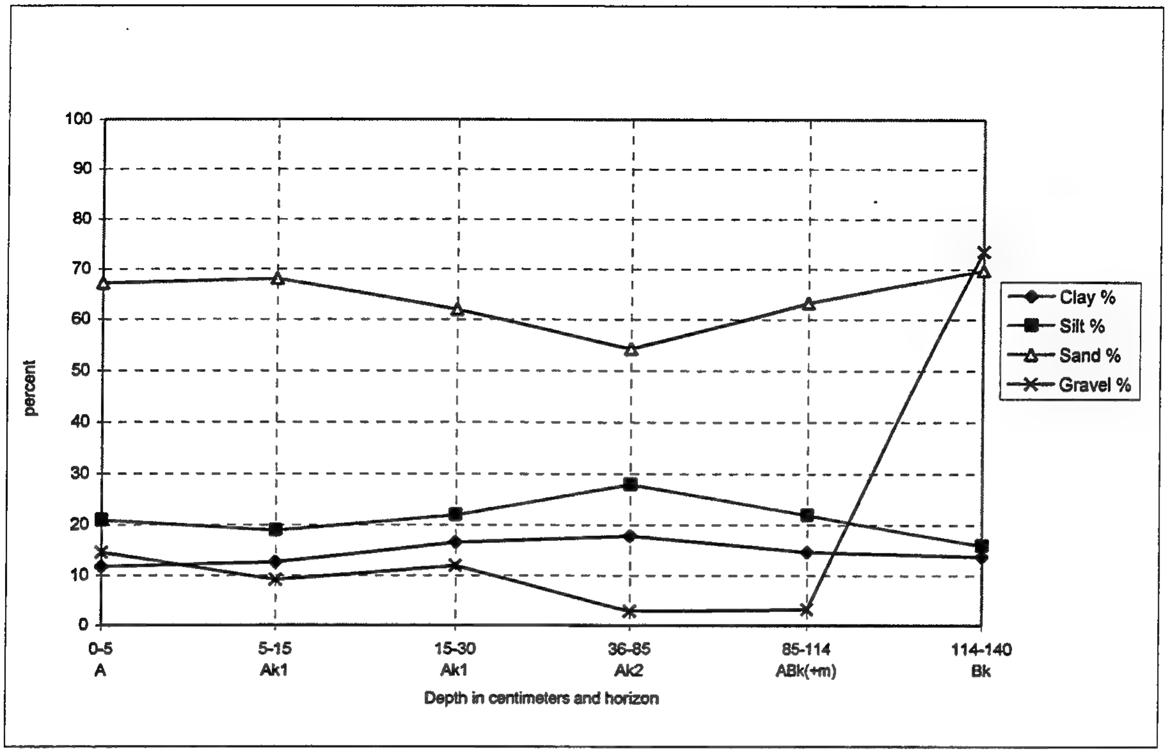
Table 15
Stone School, Site 42, McGregor Range, New Mexico
Particle Size and Chemical Data

Particle Size Data

Horizon	Depth	Sediment / Percent: Clay	Silt	Sand	Fine Silt	Coarse Silt	Very Fine Sand	Fine Sand	Medium Sand	Coarse Sand	Very Coarse Sand	Gravel	Textural Class
A	0-5	11.80	21.00	67.20	9.00	11.90	36.40	29.50	0.70	0.50	0.20	14.60	VFSL
Ak1	5-15	12.70	19.00	68.10	8.20	11.00	37.70	28.40	0.90	0.60	0.50	9.20	VFSL
Ak1	15-30	16.60	22.00	62.00	8.40	13.10	37.70	22.70	0.60	0.50	0.50	12.00	VFSL
Ak2	36-85	17.90	28.00	54.30	9.30	18.40	36.20	14.60	0.80	1.00	1.70	2.90	VFSL
ABk(±m)	85-114	14.70	22.00	63.30	7.10	15.00	39.70	20.90	0.80	0.90	0.90	3.30	VFSL
Bk	114-140	13.80	16.00	69.80	7.80	8.60	25.50	21.90	5.40	8.10	8.90	73.60	FSL

Chemical Data

Horizon	Depth	Ca meq/100g	Mg meq/100g	Na meq/100g	K meg/100g	Sum of Bases meq/100g	Acidity meq/100g	Al meq/ 100g	CEC by sum of cations meq/100g	CEC-7 (NH4OAc) meq/100g	CEC Bases + Al	Al Sat %	Base Sat by sum %	Base Sat by CEC-7 %	Organic Carbon %	Salt pH .01M CaCl2	Water pH
A	0-5	42.50	1.60	TR	0.80	44.90	0.00	--	44.90	12.20	--	--	100.00	100.00	0.40	7.70	8.20
Ak1	5-15	44.40	1.20	TR	0.70	46.30	0.00	--	46.30	11.20	--	--	100.00	100.00	0.40	7.70	8.10
Ak1	15-30	47.60	1.60	0.10	0.30	49.60	0.00	--	49.60	11.70	--	--	100.00	100.00	0.50	7.70	8.10
Ak2	36-85	46.10	3.20	1.00	0.20	50.50	0.00	--	50.50	11.00	--	--	100.00	100.00	0.30	7.70	8.00
ABk(±m)	85-114	45.20	3.30	1.50	0.20	50.20	0.00	--	50.20	9.20	--	--	100.00	100.00	0.20	7.70	8.00
Bk	114-140	60.50	3.60	2.80	0.20	67.10	0.00	--	67.10	7.90	--	--	100.00	100.00	0.30	7.70	7.70



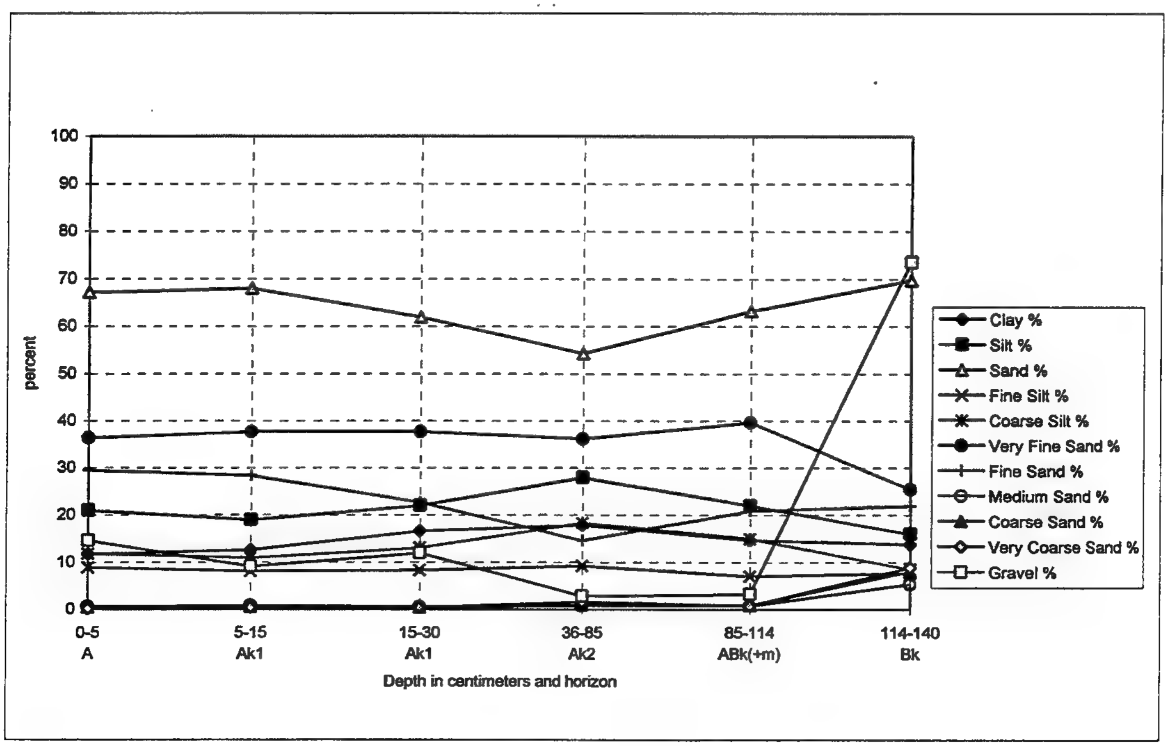
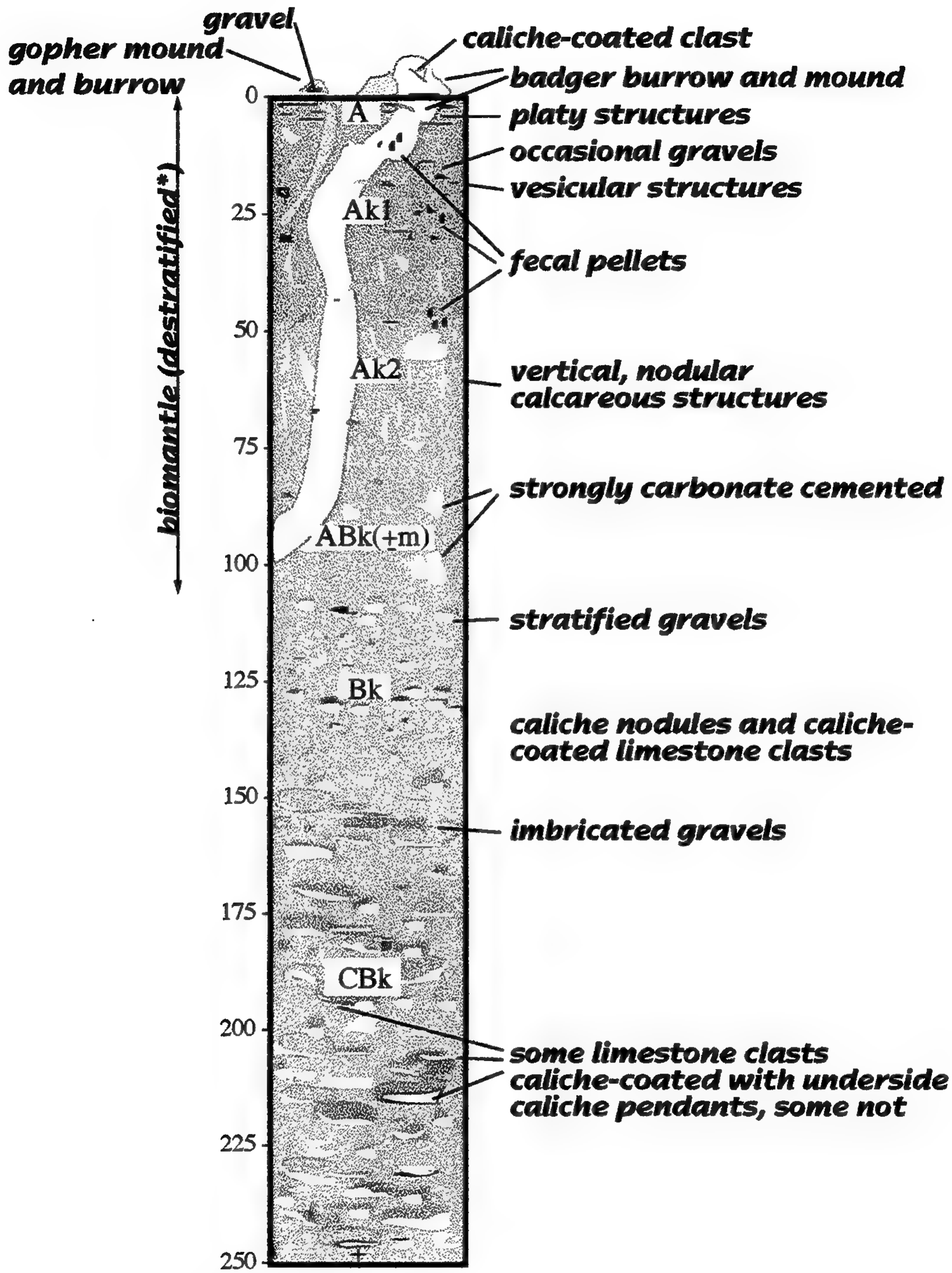


Figure 97. Stone School, site 42, depth functions of four (upper) and 11 (lower) particle sizes (data from Table 15).



*A1 is undergoing destratification.

Figure 98. Profile schematic of pedons at site 42, Stone School, McGregor Range, New Mexico.

Table 16
Length (Long Axes) of Largest Stones from 100 Badger Mounds
(in an 83-x-159-m area surrounding Stone School site backhoe pit, McGregor Guided Missile Range, Fort Bliss)

Mound #	Length (cm)	Mound #	Length (cm)	Mound #	Length (cm)	Mound#	Length (cm)
1	10	26	7	51	13	76	14
2	8	27	9	52	13	77	8
3	5	28	6	53	13	78	8
4	6	29	11	54	6	79	13
5	7	30	13	55	6	80	13
6	8	31	8	56	7	81	10
7	8	32	11	57	6	82	8
8	10	33	29	58	14	83	15
9	6	34	12	59	6	84	6
10	13	35	9	60	7	85	11
11	4	36	12	61	10	86	6
12	10	37	7	62	10	87	7
13	6	38	11	63	7	88	7
14	7	39	9	64	5	89	7
15	6	40	11	65	13	90	6
16	7	41	5	66	10	91	24
17	6	42	12	67	9	92	17
18	14	43	11	68	8	93	12
19	6	44	7	69	12	94	11
20	6	45	6	70	6	95	17
21	7	46	8	71	7	96	10
22	12	47	7	72	6	97	6
23	10	48	7	73	15	98	10
24	11	49	5	74	8	99	8
25	7	50	7	75	7	100	8

If the Dust Pit profiles exposed in the backhoe pit are generally representative of profiles all across the fan-apron here, apart from slope considerations they demonstrate the efficacy of biomechanical and biochemical interactions in producing typical fan-apron profiles in the area.

Some ovate kangaroo rat[9] fecal pellets 2-3 mm in diameter and composed of organic silt, were collected at the base of the Ak2 horizon (60-70 cm depth) and were submitted for ^{14}C analysis. Both the organic and inorganic ($CaCO_3$) carbon fractions were dated, respectively, yielding ages of $1{,}080 \pm 110$ and $9{,}200 \pm 70$ radiocarbon years before present (see Table 1, Appendix A). The disparity in the ages, specifically the much older inorganic carbon date, is attributed to dead radiocarbon contamination of the inorganic ($CaCO_3$) carbon fraction which presumably came from the Permian limestone rocks that outcrop upslope. Nevertheless, the significance of the organic carbon date is that: (1) organic materials are preserved in the sediments (rodent dung was observed in the profiles of most backhoe pits); (2) kangaroo rats had a nest here a thousand or so years ago; and (3) the krotovina in which the dung was presumably deposited is either not discernible or it no longer exists and has been destroyed by subsequent bioturbation. The fact that vertebrate dung is not uncommon in McGregor sediments and soils means that they can be dated, where the AMS method can be used to date small individual pellets or charcoal pieces.

9 Identified by Walt Whitman, NMSU mammalogist and kangaroo rat specialist (personal communication 1996).

Figure 99. Two views of badger bioturbation on the McGregor Range. Left view shows the largest 10 stones of 100 collected from a like number of badger mounds in a 83-by-159-m rectangular area (13,197 m^2) around the Stone School backhoe pit (see Table 16). Most of the thousands of stones dug up by badgers in this plot were far smaller—small cobble and pebble size—with the average long-axis diameter of the largest stone from each mound being 9.3 cm. Right photo shows a typical badger burrow on a thin historic sand sheet above a Doña Ana-like soil between Desert and the Jarilla Gap just west of Perimeter Road. Here the badger has penetrated the petrocalcic horizon.

Figure 100. Stone School Road area. The upper photo, taken between Flat Tank and Stone School, shows a two-layered faunalmantle, with a homogenized upper layer (topsoil) above a basal large clast stone-line (stone-zone) over a laminar petrocalcic (caliche) horizon. Such two-layered faunalmantles on the McGregor Range are produced by shallow burrowing rodents (small burrows) and deep burrowing badgers (two large oblate burrows). Lower photo, taken east of Stone School, shows a rodent-generated biomantle above a petrocalcic horizon. No stone-zone exists because the alluvial unit here is fine grained and lacks coarse clasts within the depth of rodent (or badger) bioturbation.

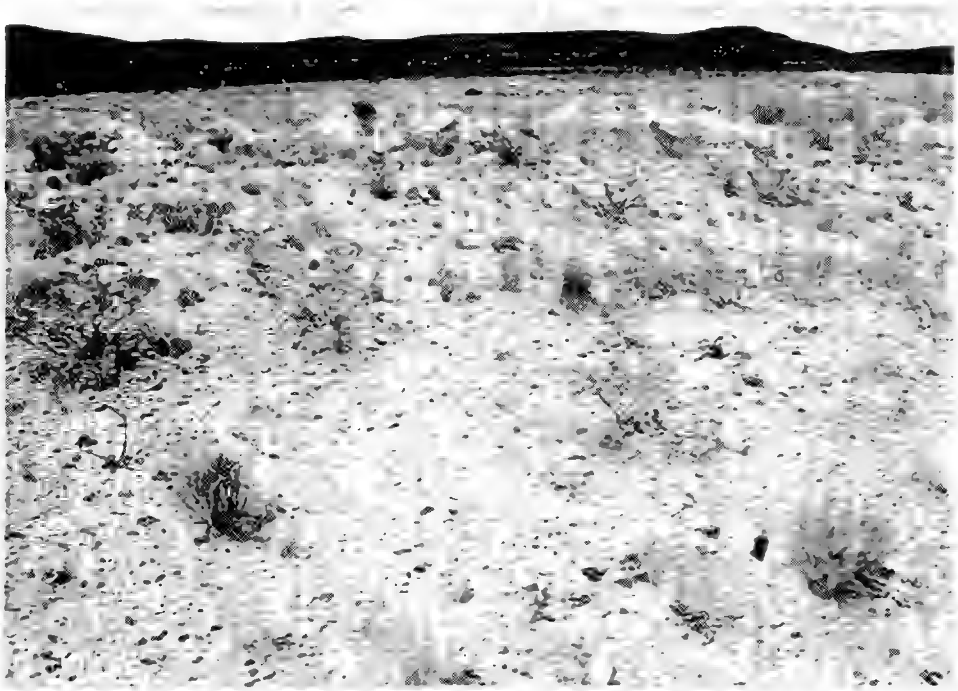


Figure 101. Stone School (site 42) area of Stone School Wash. Upper photo shows evidence of deep bioturbation by badgers in foreground (at scale), and shallow bioturbation by rodents (gophers, ground squirrels, kangaroo rats) in center right indicated by small burrow holes. Lower photo shows close-up of the badger mound and infilled burrow depression (above scale between two small brown shrubs). The deep burrowing badgers penetrate to the calcic horizon and bring caliche-coated clasts to the surface. Although it could not be quantified owing to time and other constraints, the number and bioturbational efficacy of shallow burrowing rodents, mainly gophers and ground squirrels, appear to far outweigh that of deeper burrowing badgers. One result is that two-layered faunalmantles are intermittently present in the soils on the A2, A3, and P (pediment) mapping units, as shown in Figure 100.

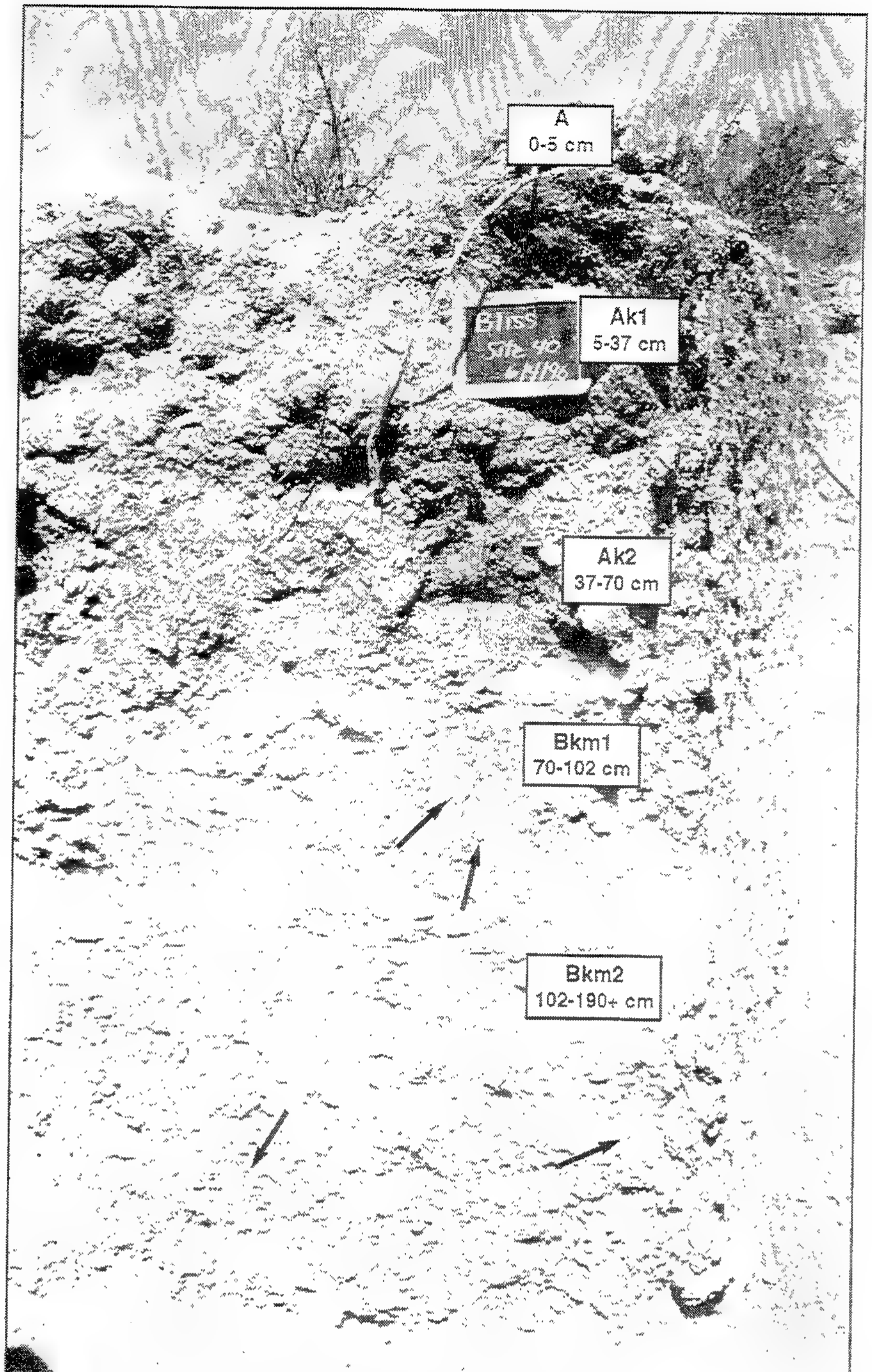


Figure 102. Dust Pit, site 40, pedon 1, soil profile. This site is on the upper midslope of an alluvial/colluvial fan that derives sediment from a ridge of limestone rock to the north and northeast. The A1, A2, and A3 horizons are destratified with abundant evidence of badger and rodent bioturbation, with new and old krotovina and burrow fillings. Fecal pellets are present in some krotovina, but also occur sporadically in the Ak1, Ak2, and Ak3 horizons, suggesting the presence of former krotovina now no longer visible. Some fecal pellets, 2-3 mm in diameter, appear composed of organic silt. Note dark krotovina in Bk1m and Bk2m horizons.

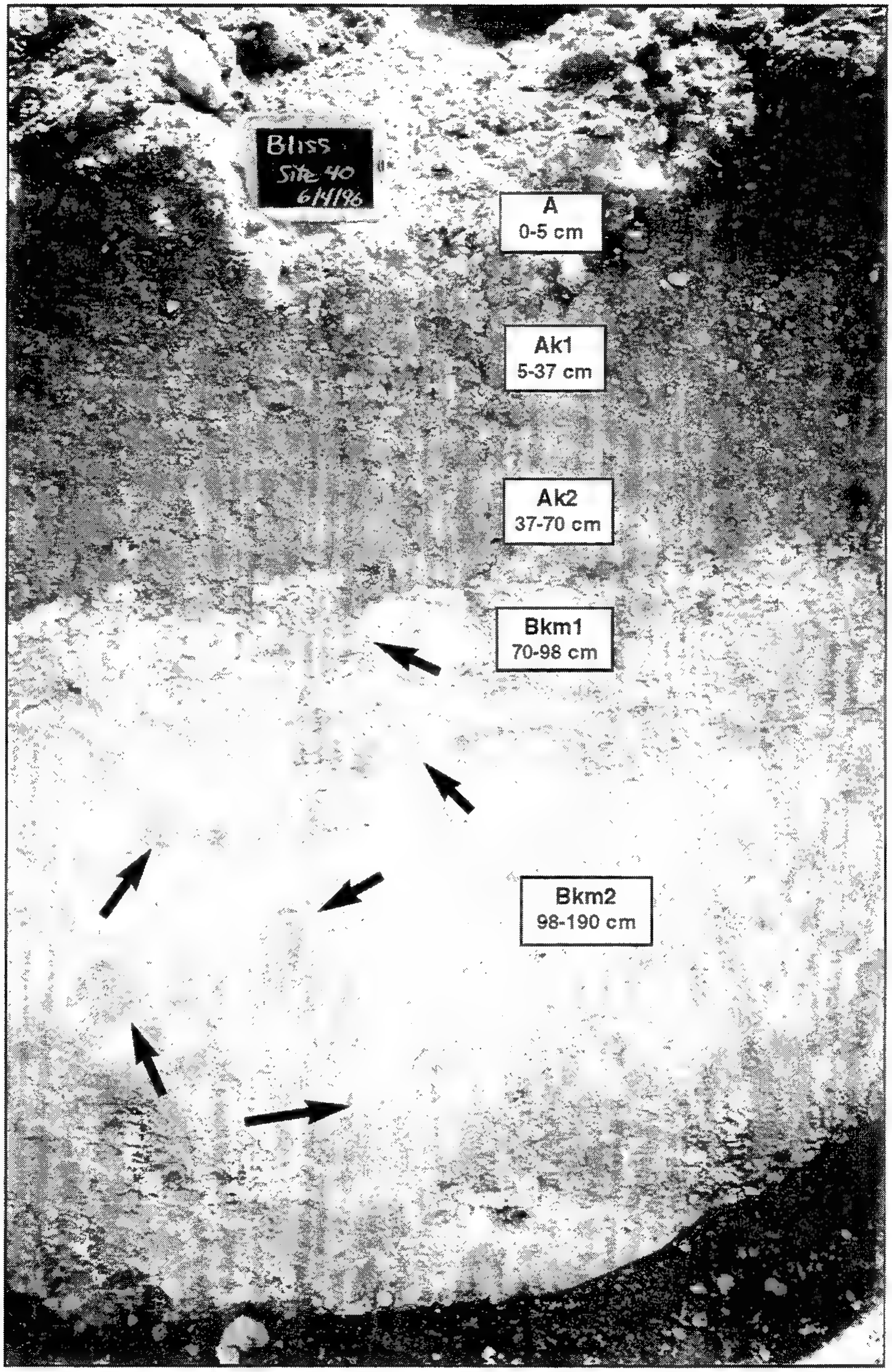


Figure 103. Dust Pit, site 40, pedon 2, soil profile. Note krotovina of different ages (see arrows) showing different stages and degrees of caliche overprinting.

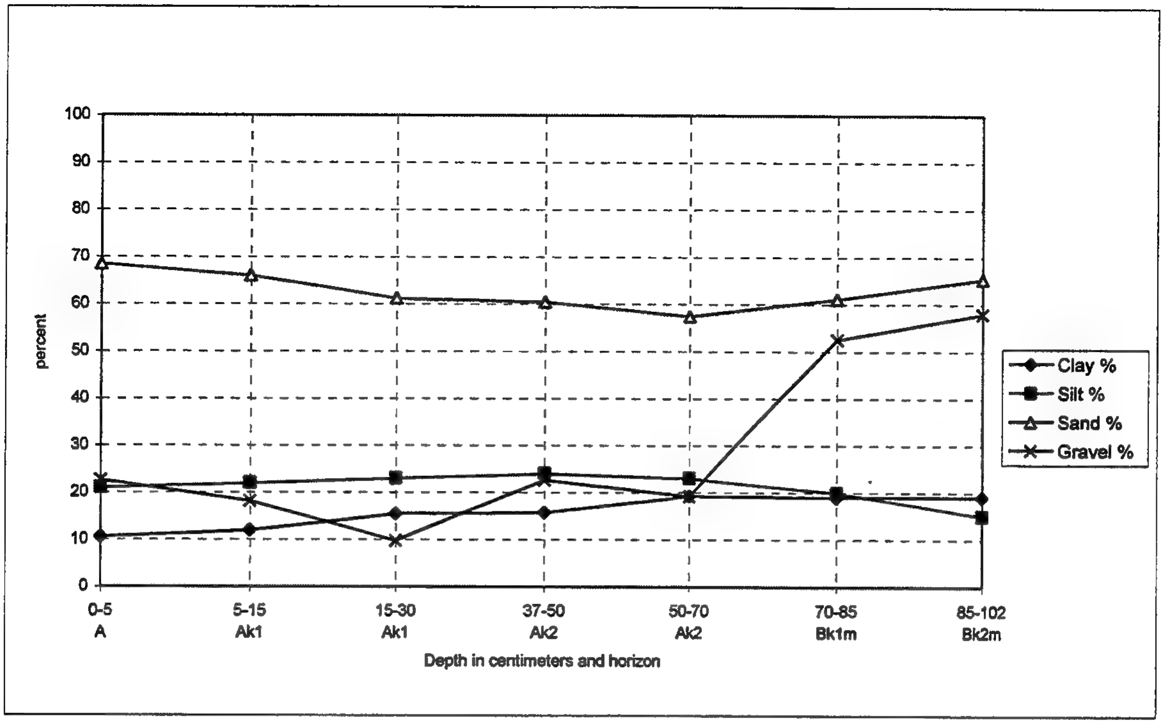
Table 17
Dust Pit, Site 40, McGregor Range, New Mexico
Particle Size and Chemical Data

Particle Size Data

Horizon	Depth	Sediment / Percent: Clay	Silt	Sand	Fine Silt	Coarse Silt	Very Fine Sand	Fine Sand	Medium Sand	Coarse Sand	Very Coarse Sand	Gravel	Textural Class
A	0-5	10.60	21.00	68.60	7.40	13.50	35.20	30.50	1.60	0.60	0.70	22.70	VFSL
Ak1	5-15	12.00	22.00	66.10	7.40	14.50	35.60	28.50	1.10	0.50	0.40	18.20	VFSL
Ak1	15-30	15.50	23.00	61.30	9.60	13.70	32.40	26.30	1.40	0.60	0.50	9.80	VFSL
Ak2	37-50	15.80	24.00	60.50	9.70	14.00	31.40	26.80	1.20	0.60	0.50	22.70	VFSL
Ak2	50-70	19.30	23.00	57.50	9.00	14.30	29.80	25.70	1.30	0.50	0.20	19.20	SL
Bk1m	70-85	19.00	20.00	61.20	8.10	11.80	28.70	26.60	1.50	1.70	2.70	52.60	SL
Bk2m	85-102	19.10	15.00	65.50	8.10	7.20	29.40	27.40	1.50	2.10	5.10	58.00	SL

Chemical Data

Horizon	Depth	Ca meq/100g	Mg meq/100g	Na meq/100g	K meg/100g	Sum of Bases meq/100g	Acidity meq/100g	Al meq/ 100g	CEC by sum of cations meq/100g	CEC-7 (NH4OAc) meq/100g	CEC Bases + Al	Al Sat %	Base Sat by sum %	Base Sat by CEC-7 %	Organic Carbon %	Salt pH .01M CaCl2	Water pH
A	0-5	45.60	2.10	TR	0.90	48.60	0.00	--	48.60	8.70	--	--	100.00	100.00	0.40	7.60	8.20
Ak1	5-15	43.40	1.60	TR	0.80	45.80	0.00	--	45.80	8.80	--	--	100.00	100.00	0.40	7.70	8.10
Ak1	15-30	46.90	1.60	0.00	0.90	49.40	0.00	--	49.40	10.10	--	--	100.00	100.00	0.50	7.60	8.10
Ak2	37-50	45.30	2.00	TR	0.90	48.20	0.00	--	48.20	9.80	--	--	100.00	100.00	0.50	7.60	8.00
Ak2	50-70	46.20	2.00	0.10	0.80	49.10	0.00	--	49.10	10.60	--	--	100.00	100.00	0.40	7.60	8.10
Bk1m	70-85	45.00	1.50	TR	0.50	47.00	0.00	--	47.00	7.20	--	--	100.00	100.00	0.40	7.70	8.10
Bk2m	85-102	44.10	1.60	TR	0.30	46.00	0.00	--	46.00	5.30	--	--	100.00	100.00	0.30	7.70	8.10



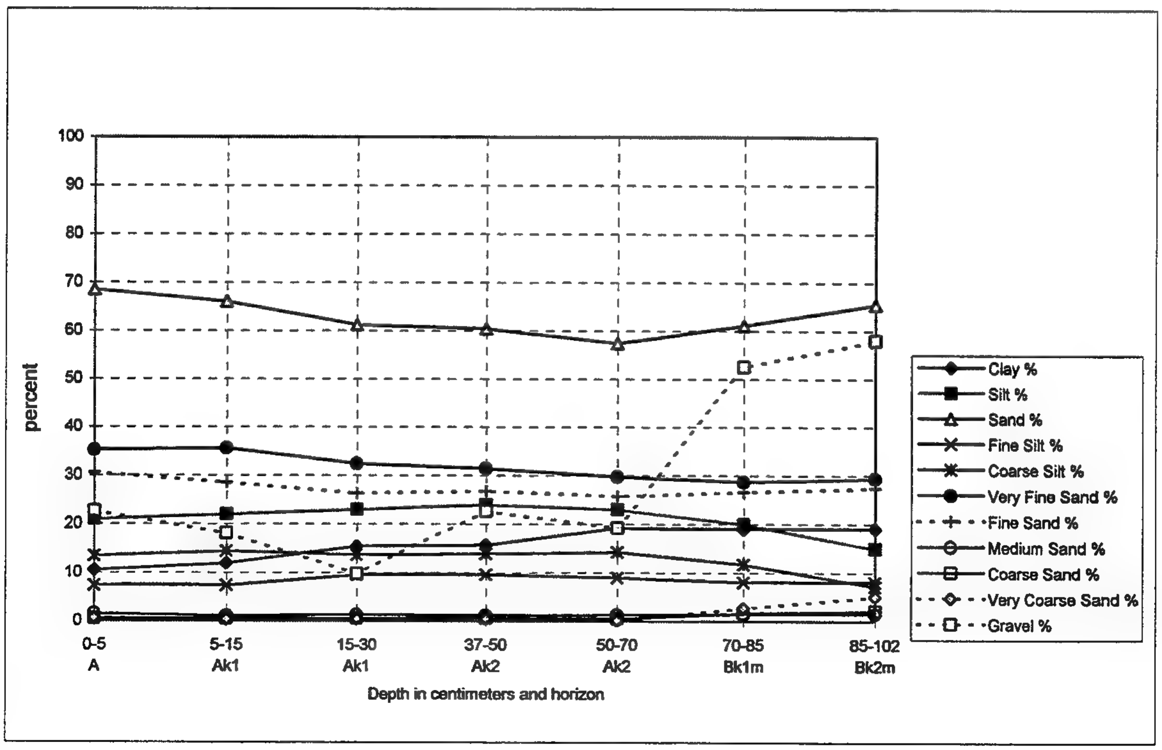
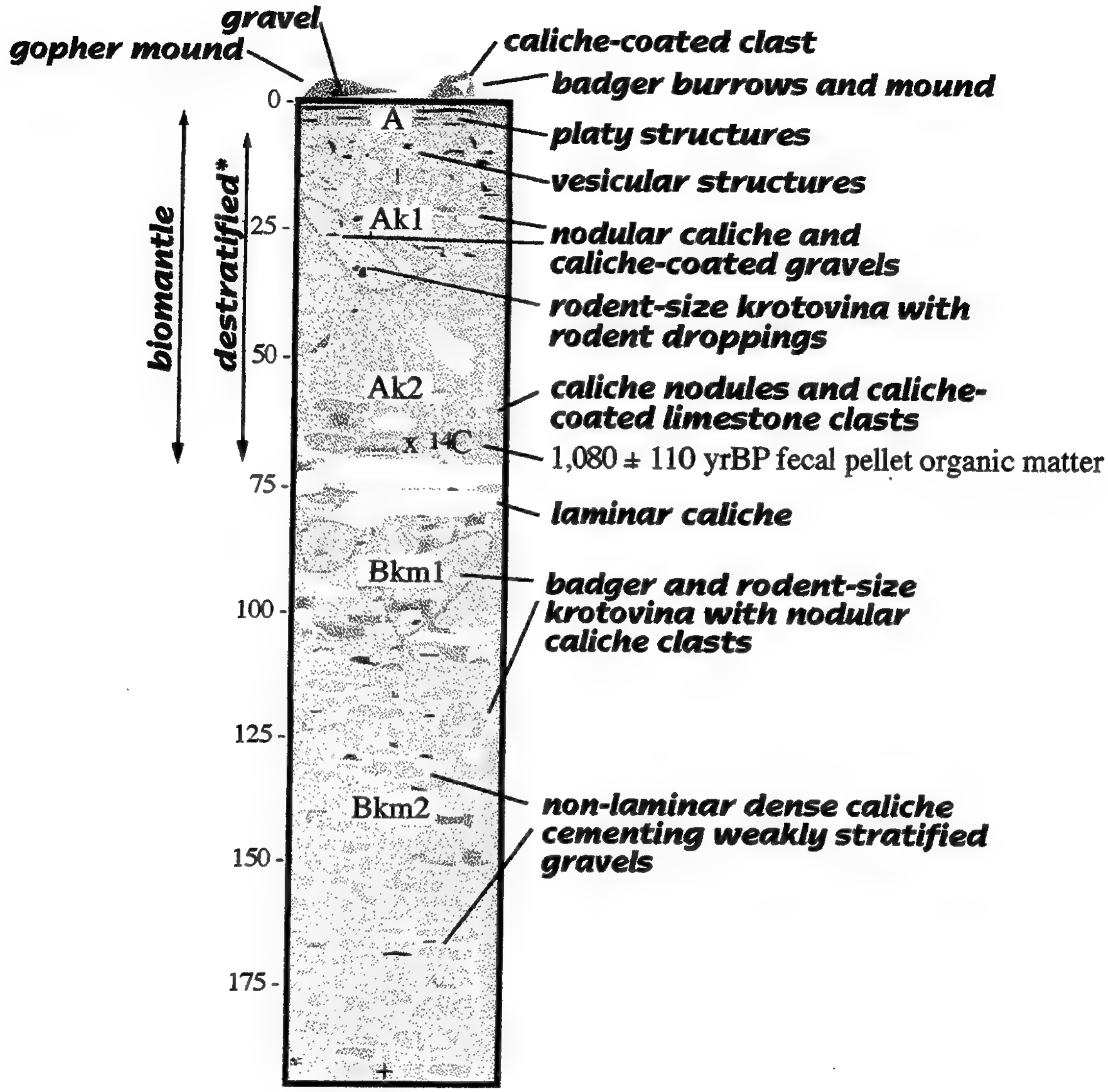


Figure 104. Dust Pit, site 40, pedon 1, depth functions of four (upper) and 11 (lower) particle sizes (data from Table 17).



* A, Bkm1, and Bkm2 are undergoing destratification.

Figure 105. Profile schematic of pedon at site 40, Dust Pit, McGregor Range, New Mexico. Kangaroo rat fecal pellets composed of organic silt collected at 60-70 cm depth gave organic and inorganic ($CaCO_3$) radiocarbon ages of 1,080±110 and 9,200±70 years, respectively (see Table 1, Appendix A). The disparity in the ages is attributed to dead radiocarbon contamination of the inorganic ($CaCO_3$) carbon fraction from Permian limestone that outcrops upslope. Nevertheless, the organic carbon date shows that: (1) organic materials are preserved in some McGregor sediments and can be dated; (2) that kangaroo rats had a nest here a thousand or so years ago; and (3) that the krotovina in which the dung was presumably deposited is either not discernible or it no longer exists, having been destroyed by subsequent bioturbation.

5. *Twin Pits, sites 41a and 41b.* Two backhoe pits were emplaced just off the southwest intersection of Borrego Ridge and South Well roads, about 1.5 miles (2.4 km) northwest of South Tank (Desert NE quad). The respective mapping units for the pits are A1 and A2. Site 41A is marginal to a broad alluvial channel, whereas Site 41B is nearby (several tens of meters) on a relict channel segment that is about 1 m higher in elevation. The descriptions of both are in Appendix D, photos of both are in Figures 106 and 107, laboratory data are in Table 18, and particle size depth functions of both are in Figures 108 and 109. Figures 110 and 111 show profile schematics of the two sites. The two sites are important because they show the range of variability of A1 and A2 mapping units on McGregor (profile 41A is a strong A1 unit, whereas 41B is close to modal). They also show two different developmental stages and display the biochemical-biomechanical vector interactions typical of soils on the alluvial fans throughout the Broken Escarpment Zone.

6. *Sulphur Tank, site 2.* This site is 5.6 miles (9 km) south of the east-west Shorad-Benton Well Blacktop, and about 50 m west of the north-south Benton Well-Sulphur Tank Road, about 200 m north of Sulphur Tank. It is on a relict alluvial surface (A2-A3 mapping Unit, Orogrande S quad). The backhoe pit, confirmed by laboratory and other augmenting data, displays graphic evidence of the relative efficacies of the biomechanical and biochemical vectors in producing nuances of the McGregor landscapes. One sediment-soil description is in Appendix D, and horizon depths were determined for two other pedons in different walls of the T-trench. A deep biomantle exists here, and its depth was measured in 16 places (see Remarks in sediment-soil description). In some pedons the biomantle was deeper than the bottom of the backhoe pit (>200 cm).

Figures 112 and 113 show three pedons which were examined in detail (pedon 1 is the described pedon). Figure 114 is a profile schematic that summarizes all pedons exposed in the pit.

Otero Mesa Zone

This zone encompasses the tablelands east of the Otero Escarpment, ranging from the eastern side of the Hueco Mountains on the south to the foothills of the Sacramento Mountains on the north. The tableland is characterized by a gently eastward sloping Permian limestone mesa that is dissected by a series of subparallel shallow east-flowing streams. The surface is basically a pediment capped with a variable veneer of pedisediment and soil, though not insignificant areas of almost bare limestone rock occur. A number of shallow karstic depressions, like Bassett Lake Playa, site 5, are present on its surface and increase in frequency towards the east. Dune patches occur here and there (e.g., Camaleche Tanks, El Paso Draw), having formed both from sand that saltated out of the Tularosa Basin and from sand released by weathering and erosion from the Permian paleosols that outcrop sporadically on the mesa (e.g., northwest side of Bassett Lake). All of the dunes examined contained prehistoric cultural resources (Figure 115).

Even though Bassett Lake is off the military reservation, it potentially offers insights to the early historic and prehistoric vegetation environment of this part of the mesa, and, by projection, the nearby upland areas of McGregor as well. Also, examination of its playa sediments would project to the nature of karstic playa sediments on McGregor managed parts of the mesa (e.g., Stone Well quad). For these reasons several hydraulic Giddings cores were pulled from the floor of Bassett Lake Playa. One was for description and soil characterization, the other for pollen analysis. The description of the core for Bassett Lake Playa, site 5, is in Appendix D, the laboratory data are in Table 19, and the depth functions of particle size are in Figure 116. Dr. Stephen A. Hall (personal communication 1996) reports the following pollen results:

> Bassett Lake. A strong disappointment is the virtual lack of pollen from the lowest core material (8-foot depth). However, the sediments are characterized by secondary carbonates and some mottling—not surprising that it has little pollen. I observed a couple of pollen grains and I estimate, based on spike

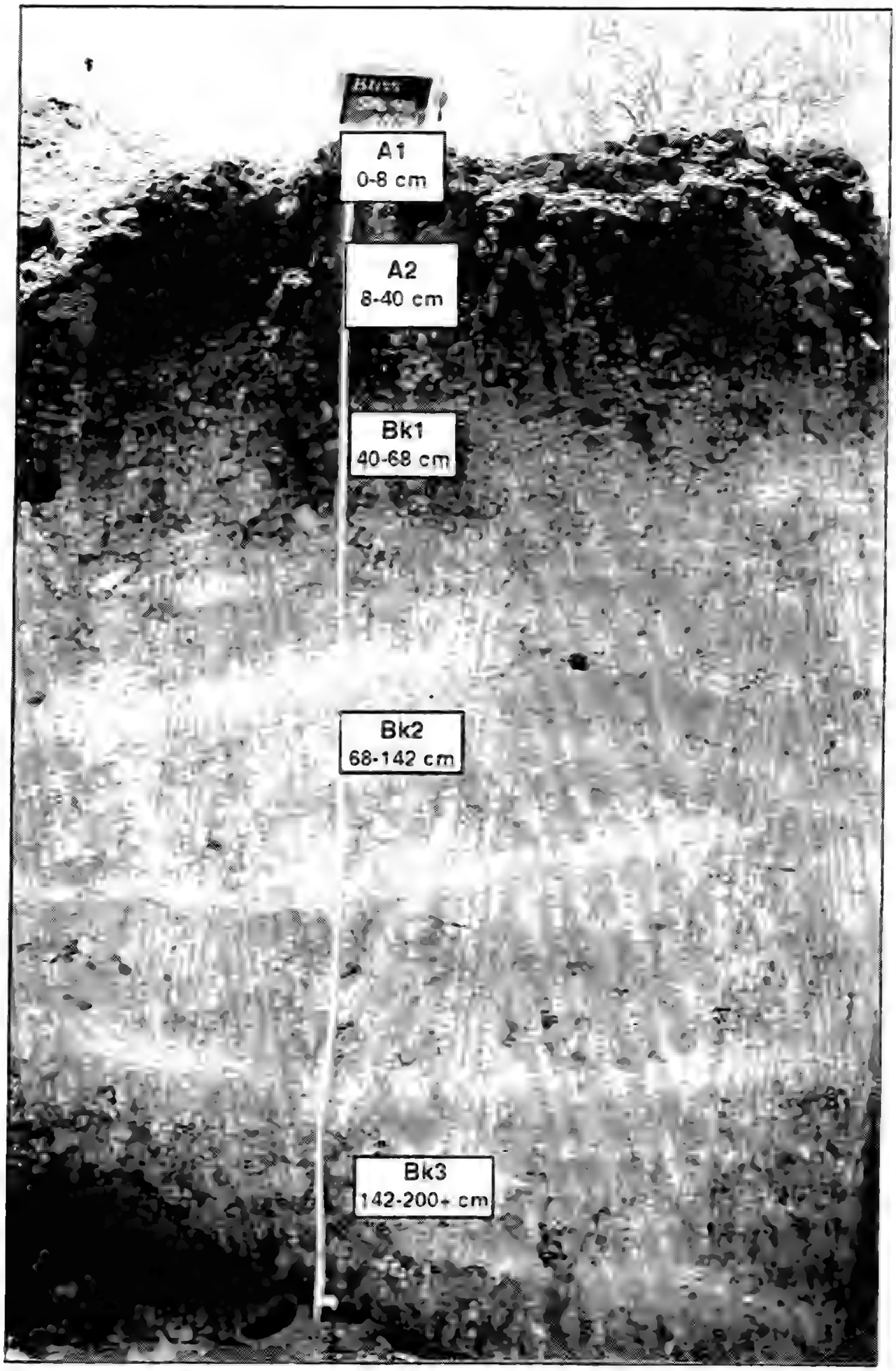


Figure 106. Twin Pits, site 41a, stratigraphy. The site is on the upper lower slopes of an alluvial fan derived from limestone rocks, a few tens of meters northeast site 41b. The T-trench exposure has no laminar caliche except one 40-cm-wide zone at the upper Bk1 horizon. Common signatures of bioturbation include abundant small krotovina, nodular calichified clasts tipped at all angles, and occasional cylindrical krotovina tipped randomly through A2, Bk1, and Bk2 horizons. Some cylindrical, vertical biochannels are present in the upper Bk2 horizon. Gravels in the upper profile and fine fraction in the lower suggest that the fan has been dynamically reactivated. (The light colored horizontal-arcuate marks are from the backhoe teeth.)

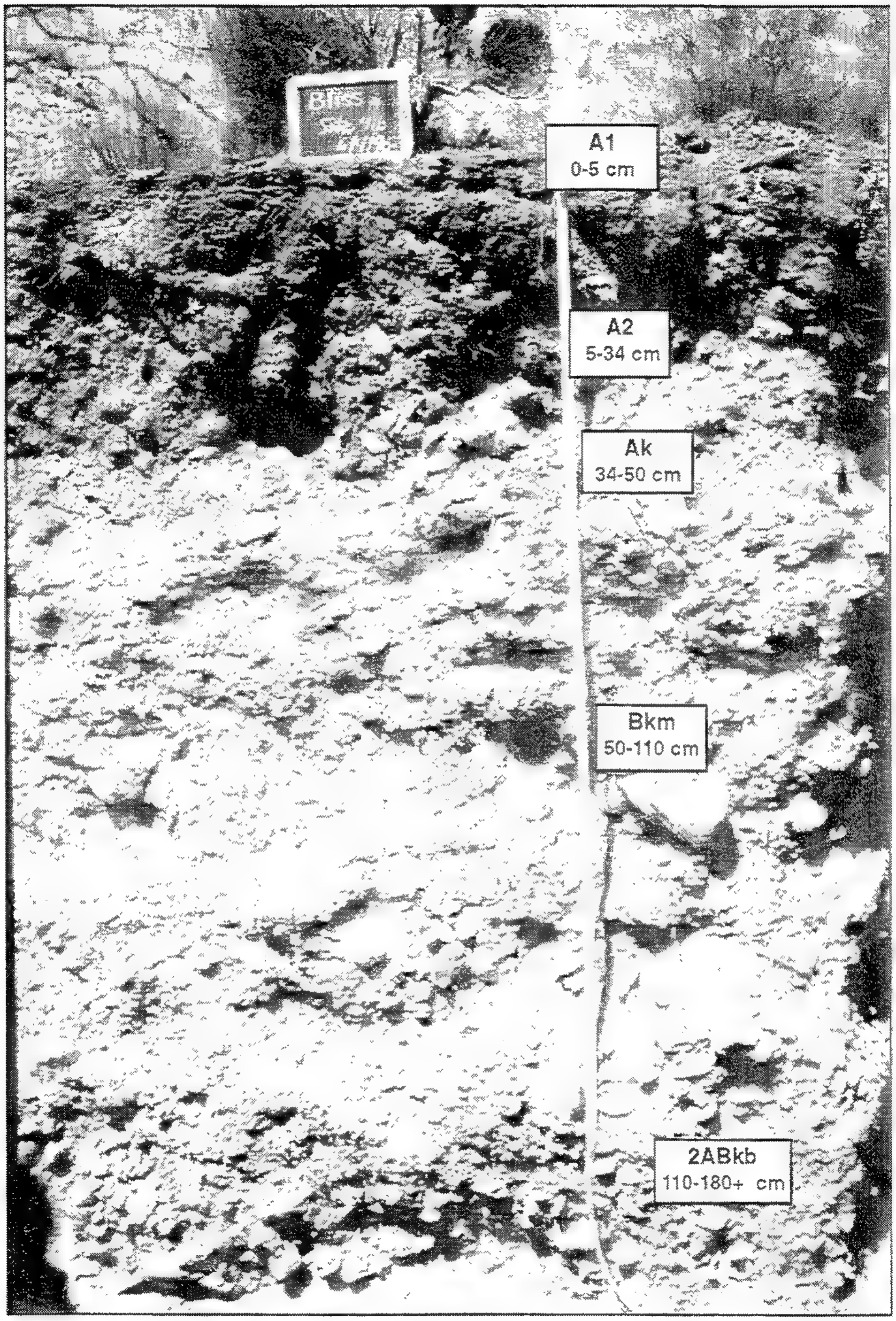


Figure 107. Twin Pits, site 41b, stratigraphy. The site is a relatively relict surface on the upper lower slopes of an alluvial fan derived from limestone rocks, a few tens of meters southwest of site 41a and about a meter higher in elevation. All pedons are strongly bioturbated here and there (note darker colored areas within caliche-enriched zone), presumably by badgers and rodents, and in places the Ak and Bkm horizons are obliterated (but not in this photo). One giant krotovina measured 64 cm in diameter at the top of the Bkm horizon and narrowed to 41 cm at 112 cm depth in the 2ABkb horizon. Other krotovina are ≥15 cm in diameter and occur within the Bkm horizon.

Table 18
Twin Pits, Site 41a and Site 41b, McGregor Range, New Mexico
Particle Size and Chemical Data

Particle Size Data Site 41a

Horizon	Depth	Sediment / Percent Clay	Silt	Sand	Fine Silt	Coarse Silt	Very Fine Sand	Fine Sand	Medium Sand	Coarse Sand	Very Coarse Sand	Gravel	Textural Class
A1	0-8	20.10	31.00	48.50	15.90	15.50	31.20	16.40	0.50	0.20	0.20	0.30	L
A2	8-20	27.30	30.00	42.80	20.90	9.00	22.80	19.30	0.50	0.10	0.10	0.30	CL
A2	20-40	34.40	17.00	48.30	10.80	6.50	23.30	23.50	0.80	0.20	0.40	8.60	SCL
Bk1	40-55	27.30	18.00	54.70	9.30	8.70	26.40	27.20	0.60	0.20	0.30	18.30	SCL
Bk1	55-68	20.70	14.00	65.40	6.00	8.00	28.50	35.20	1.10	0.30	0.30	20.70	SCL
Bk2	68-90	13.80	9.60	76.60	4.10	5.50	31.30	40.20	1.30	1.20	2.60	21.10	VFSL
Bk2	90-120	34.20	18.00	47.60	9.80	8.50	26.40	19.70	0.70	0.40	0.40	1.50	SCL
Bk2	120-142	34.90	18.00	47.50	9.80	7.80	26.20	19.90	0.60	0.40	0.40	6.50	SCL

Particle Size Data Site 41b

Horizon	Depth	Sediment / Percent Clay	Silt	Sand	Fine Silt	Coarse Silt	Very Fine Sand	Fine Sand	Medium Sand	Coarse Sand	Very Coarse Sand	Gravel	Textural Class
A1	0-5	9.20	23.00	68.30	10.10	12.40	34.00	33.20	0.80	0.20	0.10	14.90	VFSL
A2	5-15	13.80	20.00	65.90	8.70	11.60	33.90	30.80	0.60	0.20	0.30	24.80	VFSL
A2	15-30	16.40	22.00	61.70	7.80	14.10	33.40	27.00	0.90	0.30	0.20	26.40	VFSL
Ak	34-50	17.30	22.00	60.70	9.70	12.30	24.60	20.80	1.30	3.40	10.80	66.60	FSL
Bkm	50-75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	95.60	gravel
2ABkb	75-110	11.80	13.00	75.30	9.50	3.50	15.90	25.80	4.80	9.00	19.80	67.50	COSL

Chemical Data Site 41a

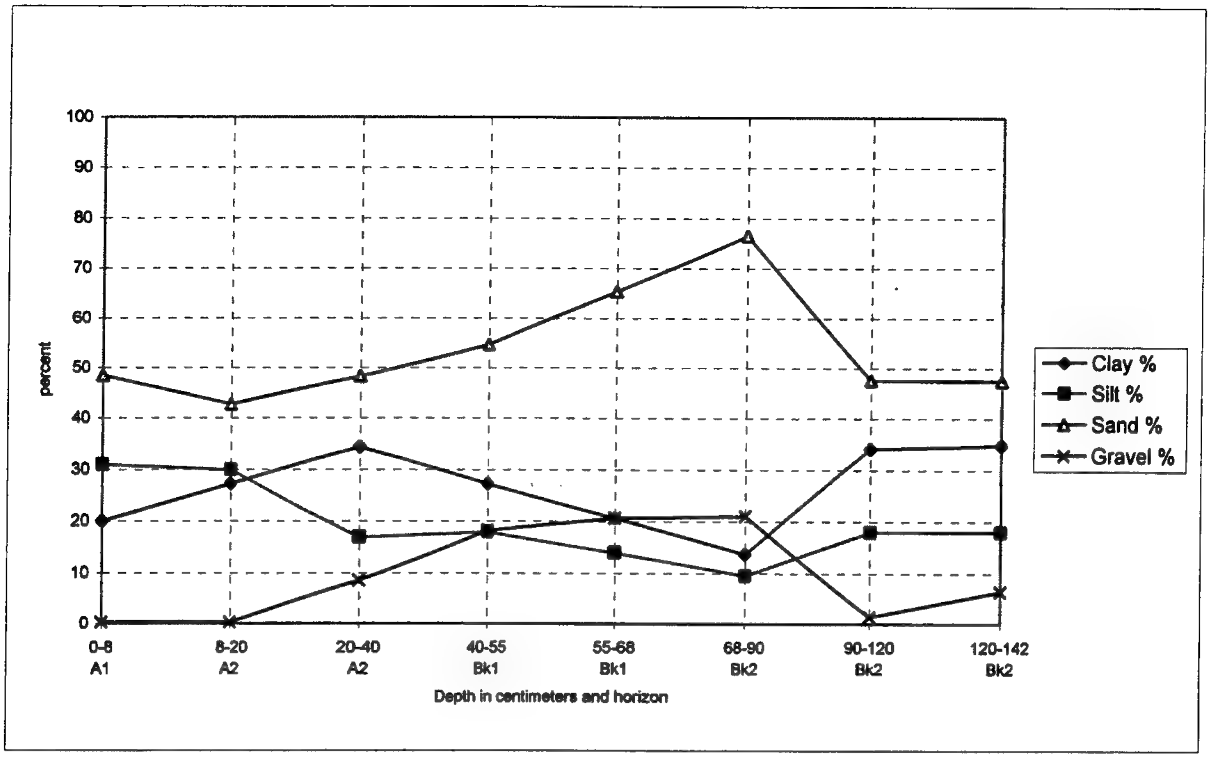
Horizon	Depth	Ca meq/100g	Mg meq/100g	Na meq/100g	K meg/100g	Sum of Bases meq/100g	Acidity meq/100g	Al meq/100g	CEC by sum of cations meq/100g	CEC-7 (NH4OAc) meq/100g	CEC Bases + Al	Al Sat %	Base Sat by sum %	Base Sat by CEC-7 %	Organic Carbon %	Salt pH .01M CaCl2	Water pH
A1	0-8	50.30	2.00	TR	1.50	53.80	0.00	–	53.80	19.00	–	–	100.00	100.00	1.10	7.60	8.10
A2	8-20	55.30	2.50	TR	1.10	58.90	0.00	–	58.90	23.20	–	–	100.00	100.00	1.10	7.60	7.90
A2	20-40	55.20	2.00	TR	0.60	57.80	0.00	–	57.80	19.90	–	–	100.00	100.00	0.80	7.60	8.00
Bk1	40-55	50.60	1.60	0.10	0.40	52.70	0.00	–	52.70	15.40	–	–	100.00	100.00	0.70	7.60	8.10
Bk1	55-68	45.70	1.20	TR	0.30	47.20	0.00	–	47.20	11.00	–	–	100.00	100.00	0.50	7.60	8.10

Table 18 (cont'd)

Horizon	Depth	Ca meq/100g	Mg meq/100g	Na meq/100g	K meg/100g	Sum of Bases meq/100g	Acidity meq/100g	Al meq/100g	CEC by sum of cations meq/100g	CEC-7 (NH4OAc) meq/100g	CEC Bases + Al	Al Sat %	Base Sat by sum %	Base Sat by CEC-7 %	Organic Carbon %	Salt pH .01M CaCl2	Water pH
Bk2	68-90	45.10	1.20	TR	0.20	46.50	0.00	--	46.50	7.40	--	--	100.00	100.00	0.30	7.70	8.10
Bk2	90-120	46.20	2.80	0.10	0.30	49.40	0.00	--	49.40	13.50	--	--	100.00	100.00	0.20	7.70	8.10
Bk2	120-142	46.10	3.10	0.10	0.30	49.60	0.00	--	49.60	12.40	--	--	100.00	100.00	0.20	7.70	8.10

Chemical Data Site 41b

Horizon	Depth	Ca meq/100g	Mg meq/100g	Na meq/100g	K meg/100g	Sum of Bases meq/100g	Acidity meq/100g	Al meq/100g	CEC by sum of cations meq/100g	CEC-7 (NH4OAc) meq/100g	CEC Bases + Al	Al Sat %	Base Sat by sum %	Base Sat by CEC-7 %	Organic Carbon %	Salt pH .01M CaCl2	Water pH
A1	0-5	38.90	1.60	TR	1.00	41.50	0.00	--	41.50	12.40	--	--	100.00	100.00	0.40	7.70	8.20
A2	5-15	47.60	1.20	TR	0.70	49.50	0.00	--	49.50	12.60	--	--	100.00	100.00	0.60	7.70	8.10
A2	15-30	43.70	1.20	0.10	0.30	45.30	0.00	--	45.30	11.40	--	--	100.00	100.00	0.50	7.60	8.00
Ak	34-50	46.40	2.00	0.10	0.20	48.70	0.00	--	48.70	9.10	--	--	100.00	100.00	0.70	7.70	8.10
Bkm	50-75	40.00	1.60	0.20	0.10	41.90	0.00	--	41.90	3.80	--	--	100.00	100.00	0.30	7.70	8.00
2ABkb	75-110	43.20	2.40	0.80	0.10	46.50	0.00	--	46.50	4.10	--	--	100.00	100.00	0.20	7.80	8.10



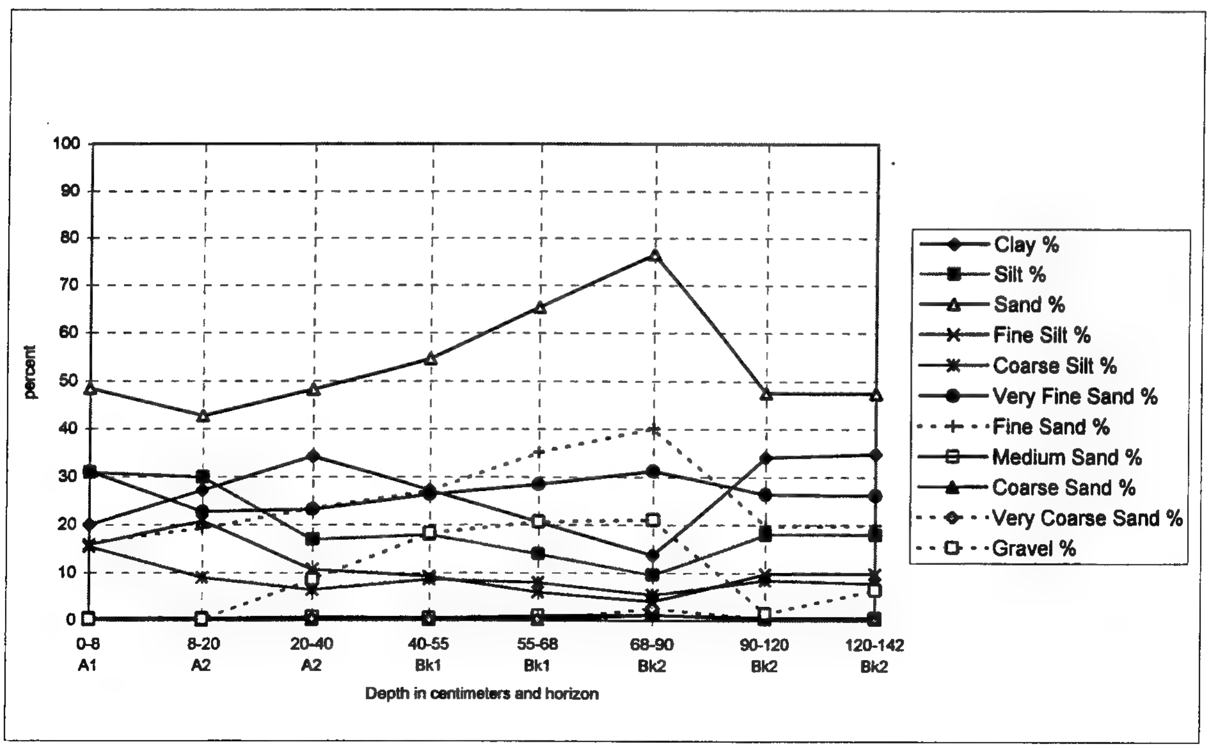
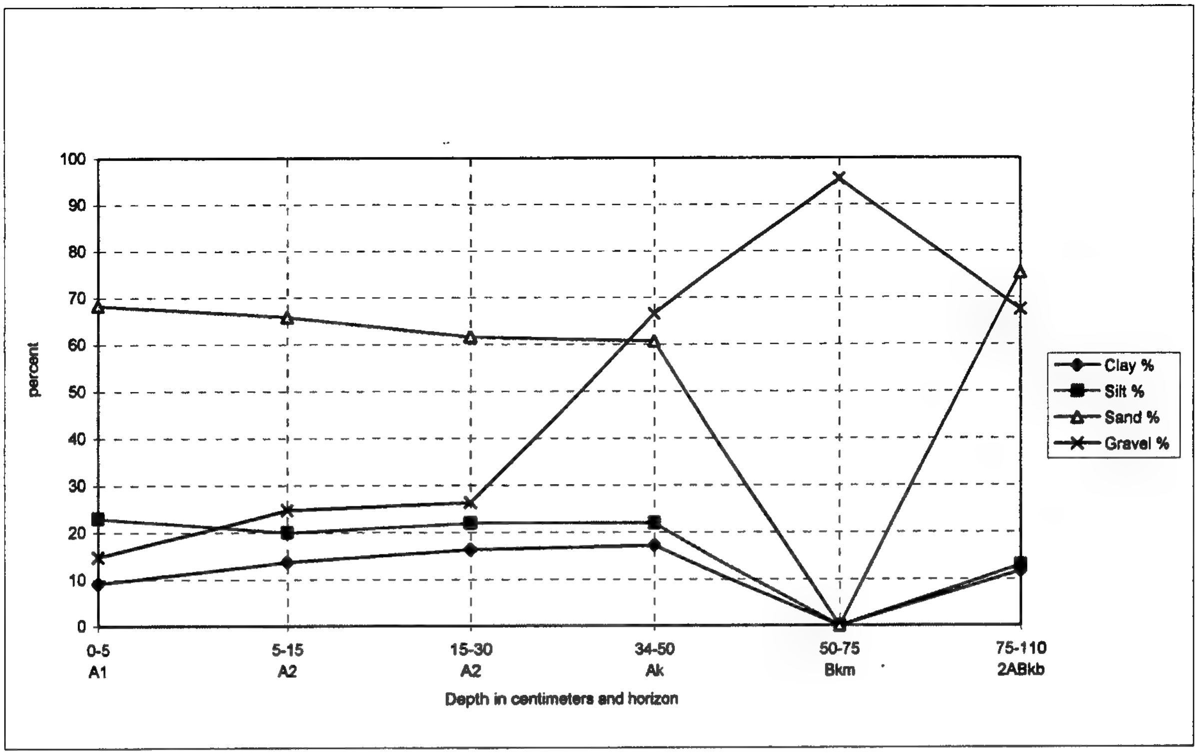


Figure 108. Twin Pits, site 41a, depth functions of four (upper) and 11 (lower) particle sizes (data from Table 18).



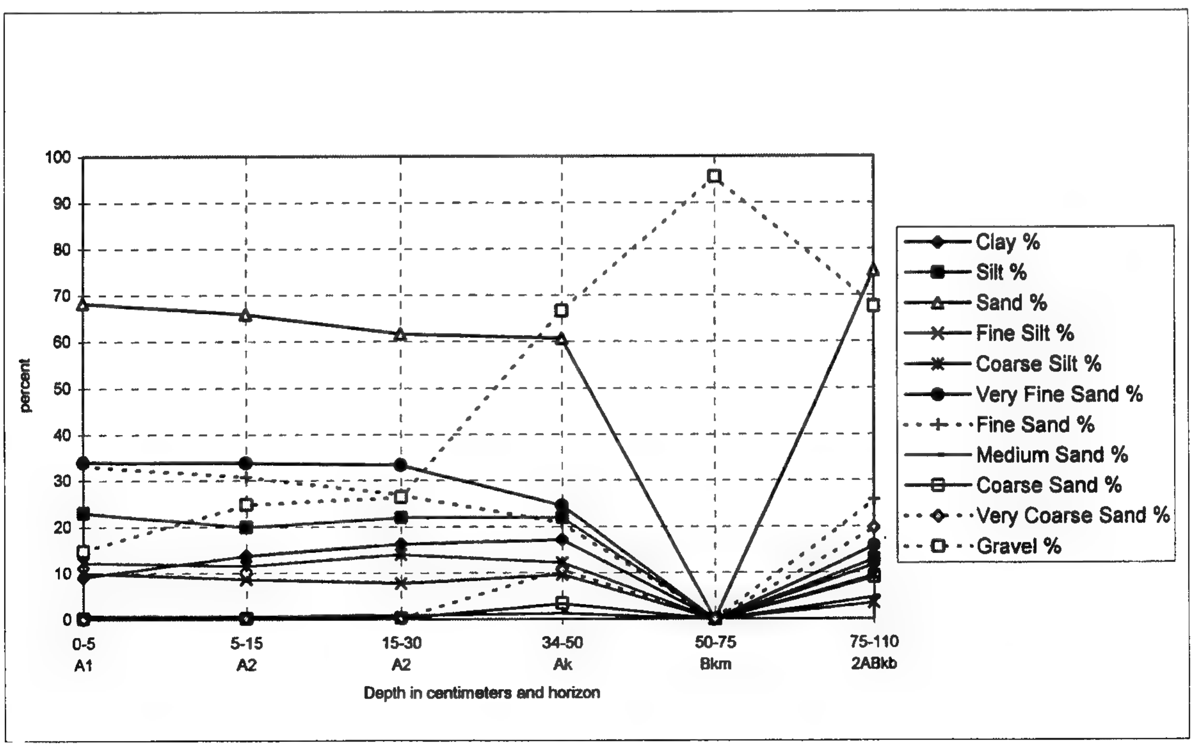


Figure 109. Twin Pits, site 41b, depth functions of four (upper) and 11 (lower) particle sizes (data from Table 18).

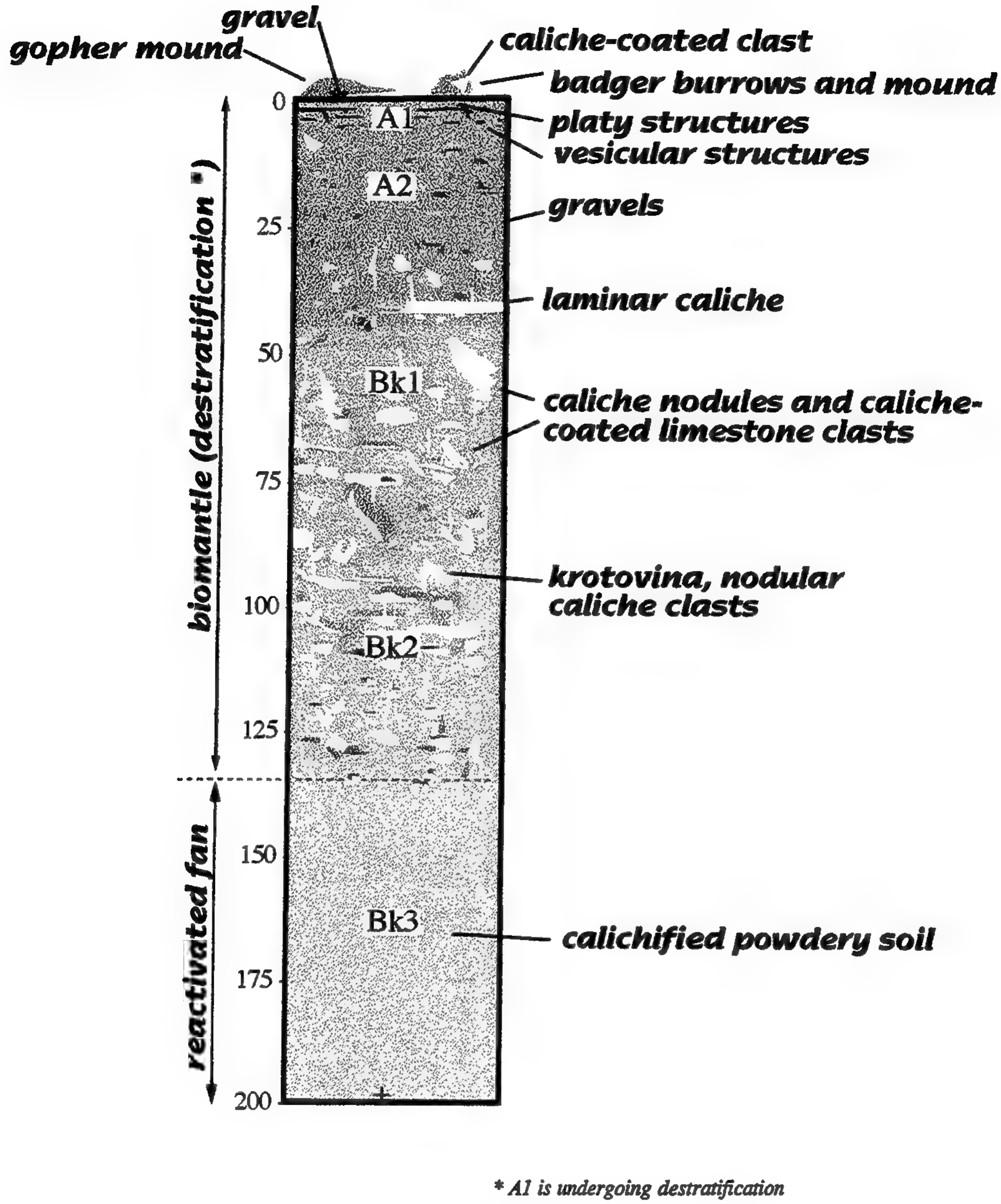
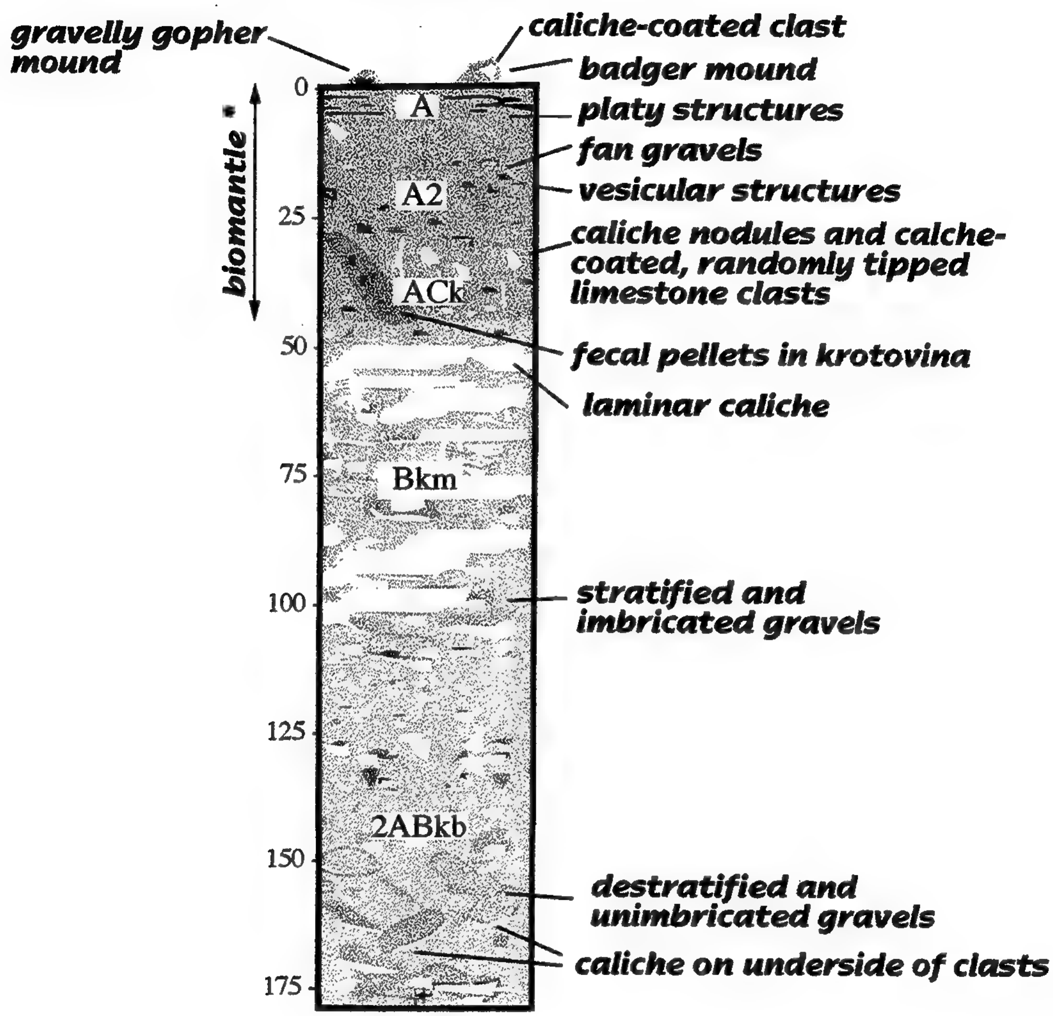


Figure 110. Profile schematic of site 41a, Twin Pits, McGregor Range, New Mexico.



* *A1 is undergoing destratification*

Figure 111. Profile schematic of site 41b, Twin Pits, McGregor Range, New Mexico.

Pedon 1 Pedon 2

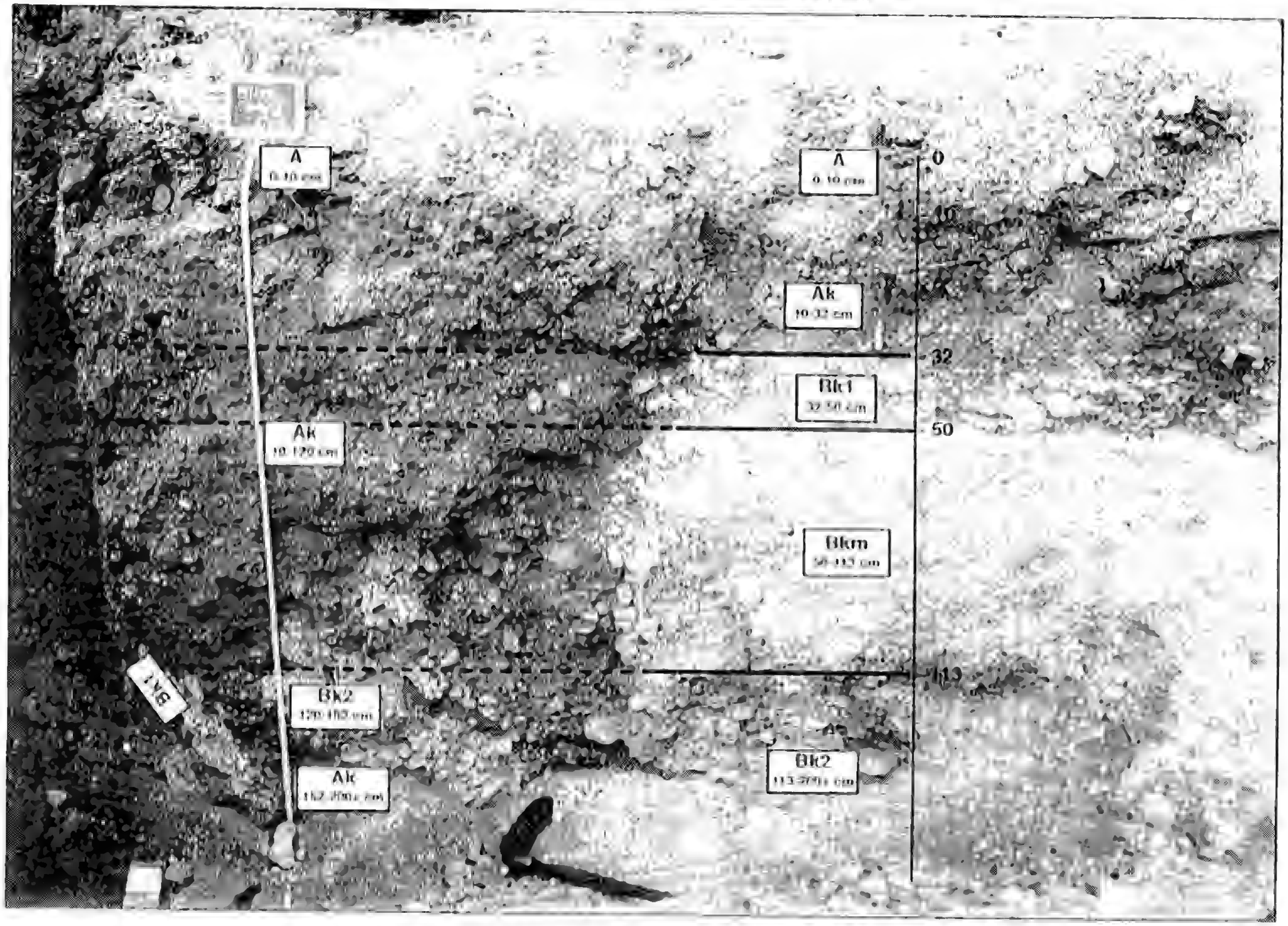


Figure 112. Sulphur Tank, site 2, pedons 1-2, profiles. East wall of pit showing pedons 1 and 2. Dashed horizontal lines represent horizons (Bk1, Bkm, and Bk2) obliterated by bioturbation, presumably by badgers. Note that a remnant of the Bk1 horizon in pedon 1 has been displaced downward almost a meter and turned upside down.

Pedon 3

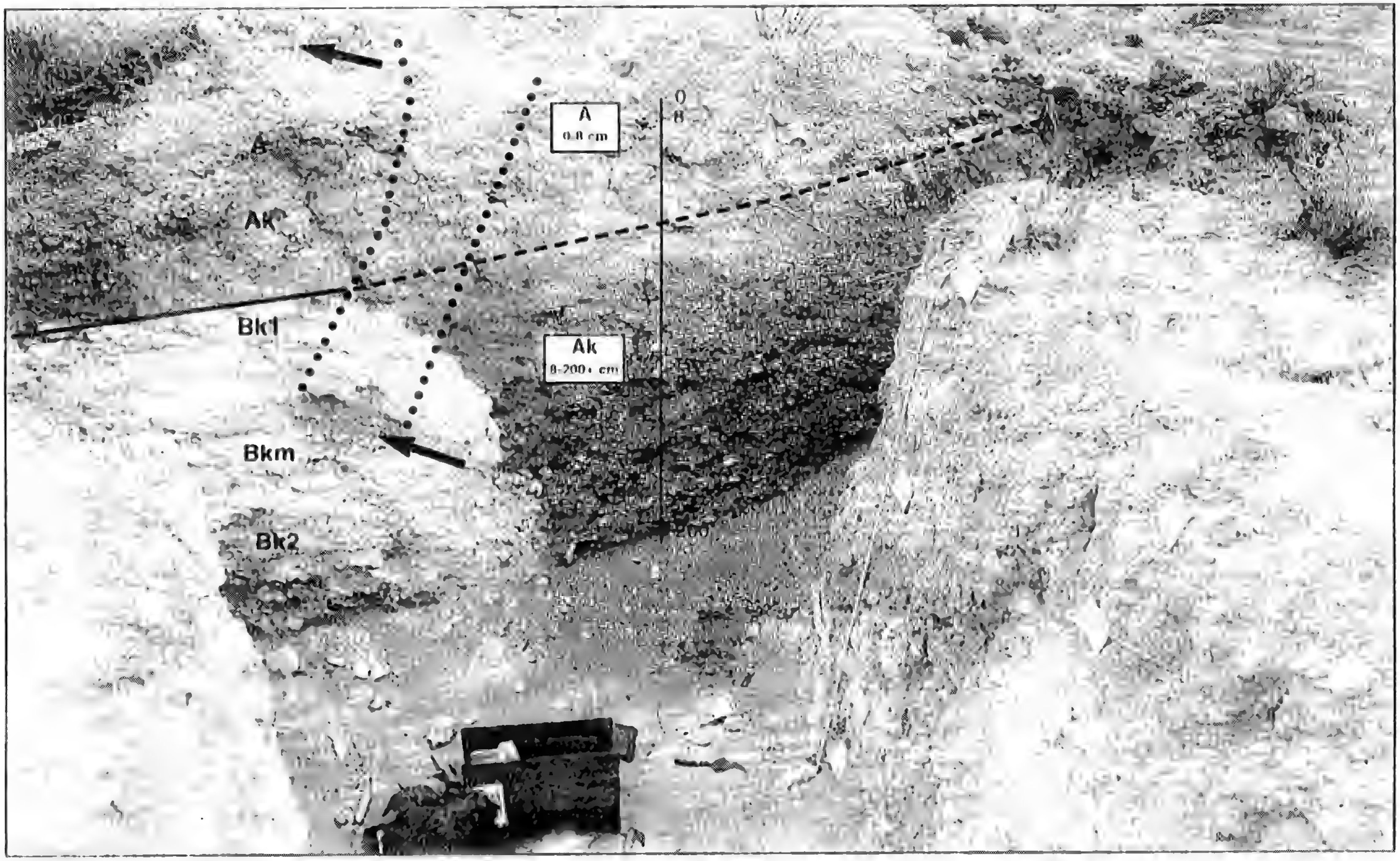


Figure 113 Sulphur Tank, site 2, pedon 3, profile. North wall of pit showing pedon 3 (pedons 1-2 visible on east wall at right). The dashed line represents the former top of the obliterated and presumably badger homogenized Bk1, Bkm, and Bk2 horizons, now represented by the Ak horizon (biomantle). Bottom arrow shows a krotovina within the Bkm horizon. Dotted lines show a possible (inferred) burrowing route three dimensionally into the pit wall and up to the surface where an infilled badger burrow is present (in slight depressional area of relatively few stones). Top arrow shows a badger spoil mound with caliche-coated stones and petrocalcic (Bkm) horizon material next to infilled burrow. Note also that post bioturbation laminar caliche has formed on the downward dipping but still intact Bkm horizon next to the deeply burrowed Ak horizon.

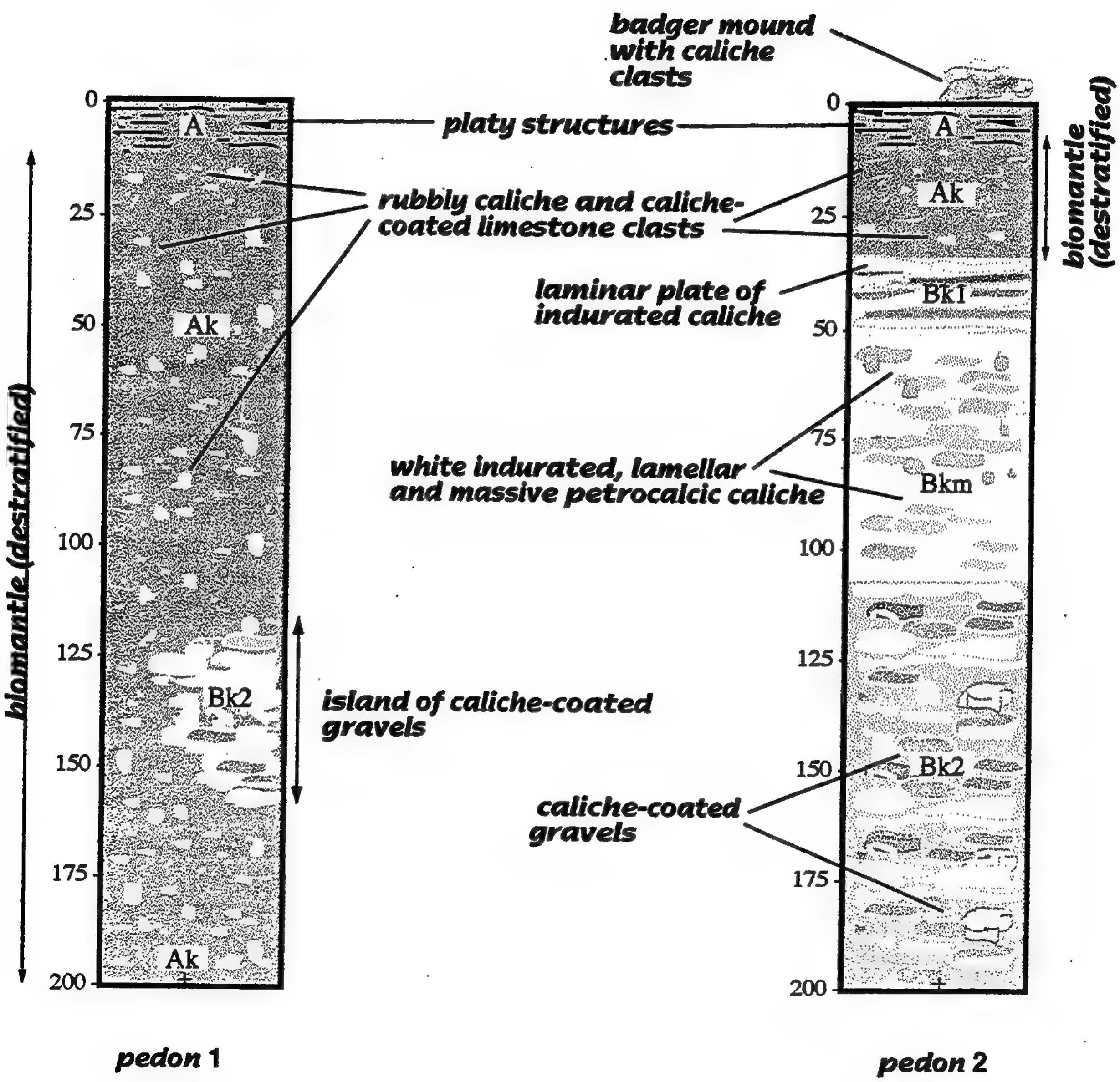


Figure 114. Profile schematic of profiles at site 2, Sulphur Tank, McGregor Range, New Mexico.

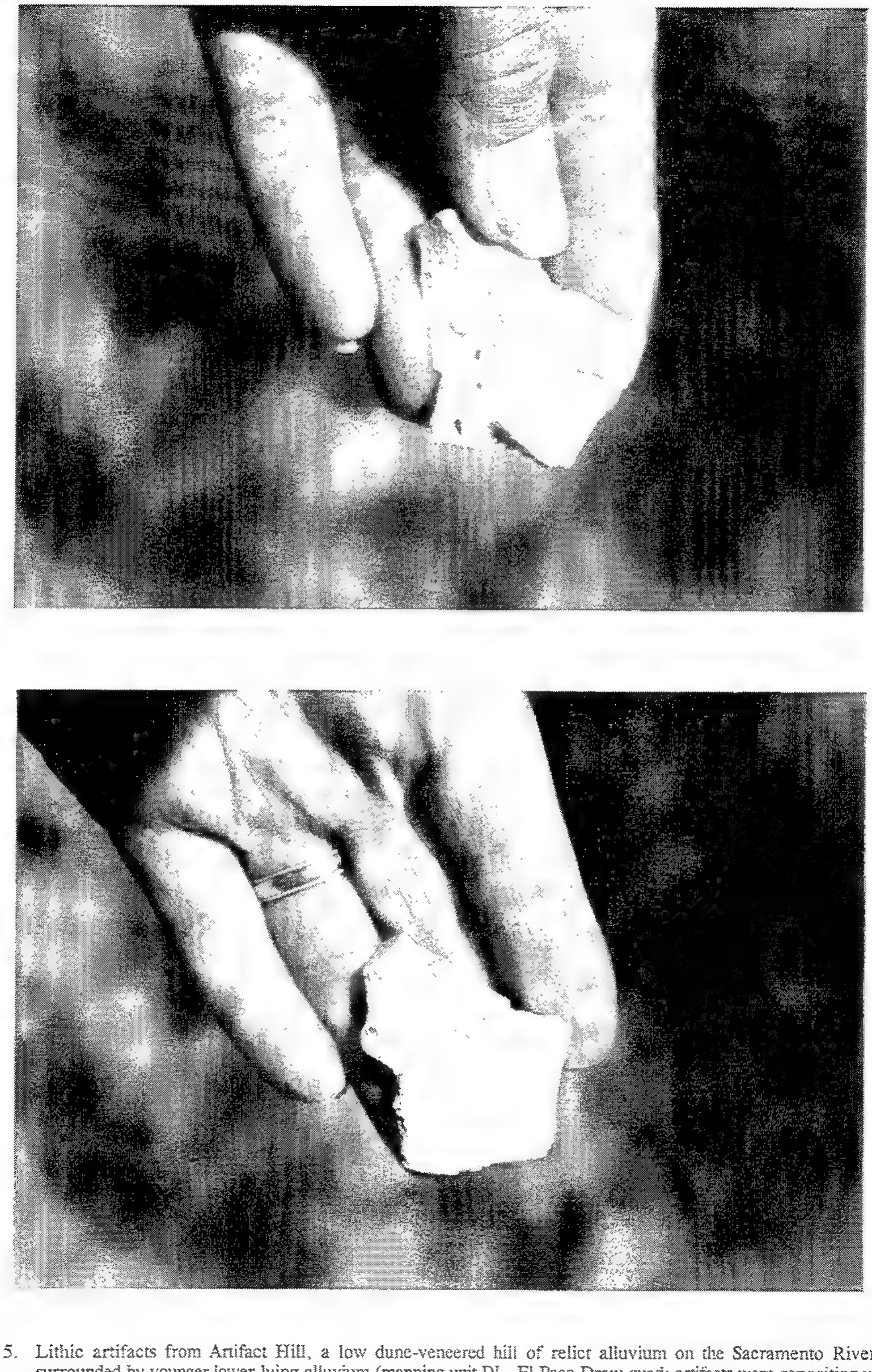


Figure 115. Lithic artifacts from Artifact Hill, a low dune-veneered hill of relict alluvium on the Sacramento River fan-delta surrounded by younger lower-lying alluvium (mapping unit DL, El Paso Draw quad: artifacts were repositioned precisely where they were picked up).

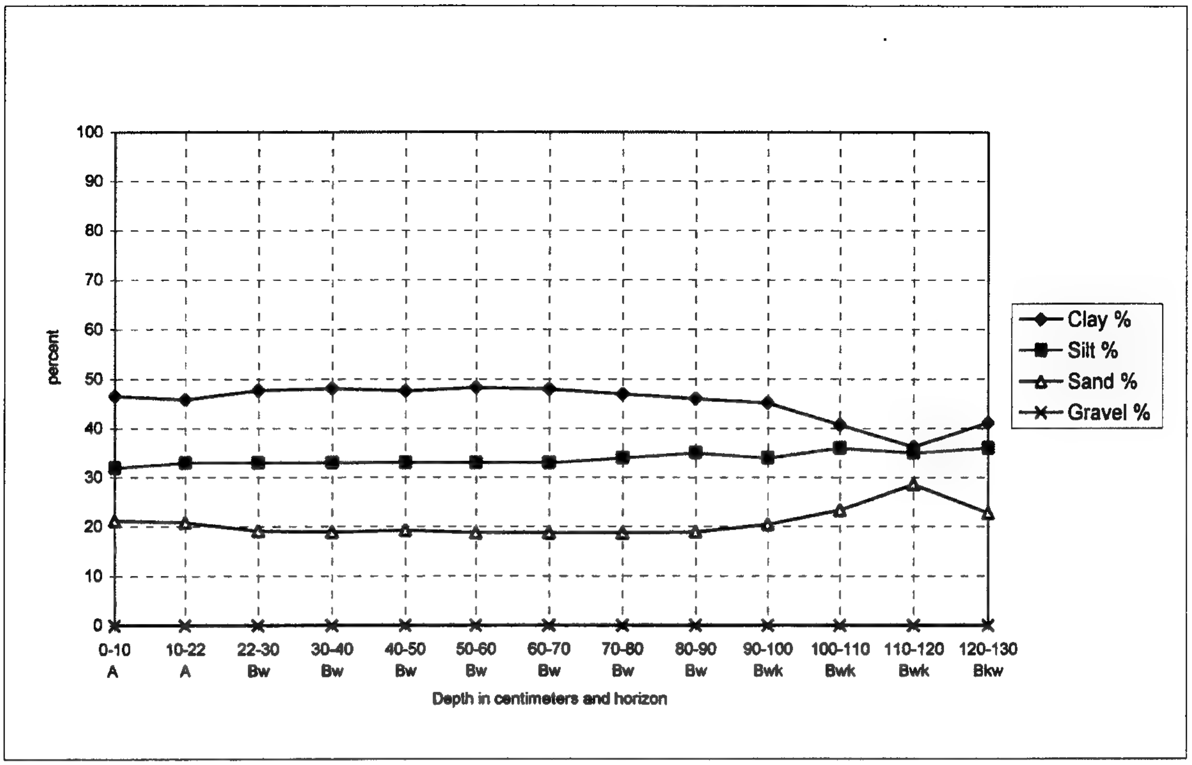
Table 19
Bassett Lake Playa, Site 5, McGregor Range, New Mexico
Particle Size and Chemical Data

Particle Size Data

		Sediment / Percent											
Horizon	Depth	Clay	Silt	Sand	Fine Silt	Coarse Silt	Very Fine Sand	Fine Sand	Medium Sand	Coarse Sand	Very Coarse Sand	Gravel	Textural Class
A	0-10	46.60	32.00	21.30	20.70	11.40	14.50	6.20	0.20	0.30	0.20	0.00	C
A	10-22	45.90	33.00	20.90	24.20	9.00	14.20	5.80	0.20	0.20	0.50	0.00	C
Bw	22-30	47.70	33.00	19.20	23.80	9.30	13.40	5.30	0.10	0.10	0.30	0.00	C
Bw	30-40	48.10	33.00	18.90	23.50	9.40	13.30	5.40	0.10	0.10	0.10	0.00	C
Bw	40-50	47.60	33.00	19.30	23.40	9.70	13.80	5.30	0.10	0.00	0.10	0.00	C
Bw	50-60	48.30	33.00	18.80	23.70	9.10	13.30	5.30	0.10	0.10	0.10	0.00	C
Bw	60-70	48.00	33.00	18.80	23.30	9.80	13.30	5.30	0.10	0.10	0.10	0.00	C
Bw	70-80	47.00	34.00	18.70	23.50	10.70	13.40	5.20	0.10	0.00	0.00	0.00	C
Bw	80-90	46.10	35.00	19.00	23.50	11.40	13.70	5.20	0.10	0.00	0.00	0.00	C
Bwk	90-100	45.20	34.00	20.50	22.30	12.00	15.20	5.10	0.10	0.10	0.10	0.00	C
Bwk	100-110	40.80	36.00	23.40	20.40	15.40	17.30	5.90	0.10	0.10	0.10	0.00	C
Bwk	110-120	36.30	35.00	28.60	18.40	16.70	20.00	8.20	0.20	0.10	0.10	0.00	CL
Bkw	120-130	41.20	36.00	22.80	21.10	14.80	17.00	5.60	0.10	0.10	0.10	0.00	C

Chemical Data

Horizon	Depth	Ca meq/100g	Mg meq/100g	Na meq/100g	K meg/100g	Sum of Bases meq/100g	Acidity meq/100g	Al meq/100g	CEC by sum of cations meq/100g	CEC-7 (NH4OAc) meq/100g	CEC Bases + Al	Al Sat %	Base Sat by sum %	Base Sat by CEC-7 %	Organic Carbon %	Salt pH .01M CaCl2	Water pH
A	0-10	53.60	2.40	0.10	3.50	59.60	2.40	--	62.00	36.00	--	--	96.00	100.00	2.60	7.10	7.30
A	10-22	46.70	2.00	TR	2.80	51.50	2.00	--	53.50	35.40	--	--	96.00	100.00	1.40	7.20	7.60
Bw	22-30	53.20	2.00	TR	2.20	57.40	0.90	--	58.30	33.70	--	--	98.00	100.00	1.10	7.30	7.60
Bw	30-40	53.80	2.30	TR	1.60	57.70	0.90	--	58.60	32.80	--	--	98.00	100.00	0.90	7.30	7.60
Bw	40-50	53.30	1.90	0.10	1.50	56.80	0.70	--	57.50	32.30	--	--	99.00	100.00	0.80	7.30	7.70
Bw	50-60	53.30	2.30	0.10	1.50	57.20	0.70	--	57.90	32.00	--	--	99.00	100.00	0.80	7.30	7.70
Bw	60-70	56.20	2.00	0.10	1.60	59.90	0.80	--	60.70	32.10	--	--	99.00	100.00	0.80	7.30	7.70
Bw	70-80	52.70	2.30	0.10	1.50	56.60	0.70	--	57.30	31.80	--	--	99.00	100.00	0.70	7.40	7.70
Bw	80-90	55.20	2.00	0.10	1.40	58.70	0.10	--	58.80	30.60	--	--	100.00	100.00	0.70	7.40	7.70
Bwk	90-100	50.70	1.90	0.10	1.40	54.10	0.50	--	54.60	29.70	--	--	99.00	100.00	0.60	7.40	7.70
Bwk	100-110	50.30	2.00	0.10	1.30	53.70	0.70	--	54.40	27.50	--	--	99.00	100.00	0.50	7.40	7.70
Bwk	110-120	47.00	1.60	0.10	1.00	49.70	1.20	--	50.90	22.90	--	--	98.00	100.00	0.40	7.30	7.70
Bwk	120-130	43.80	1.60	0.10	1.20	46.70	0.80	--	47.50	27.10	--	--	98.00	100.00	0.50	7.40	7.60



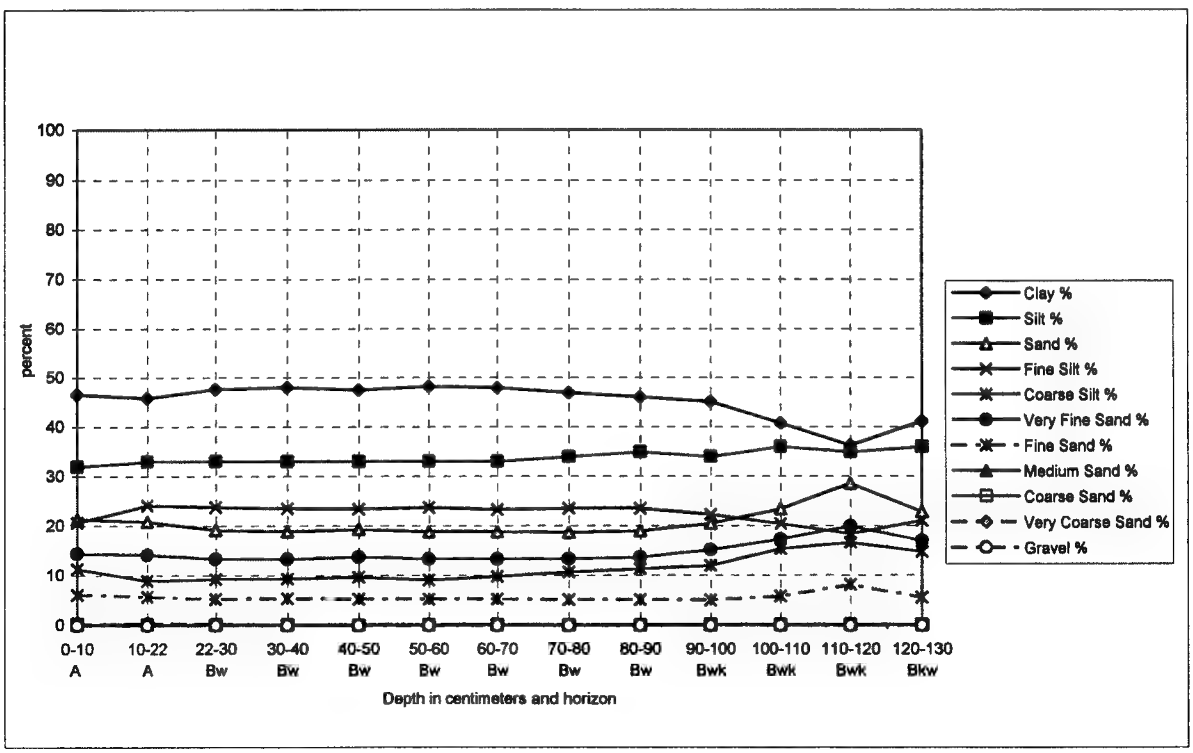


Figure 116. Bassett Lake Playa, site 5, depth functions of four (upper) and 11 (lower) particle sizes (no gravels present; data from Table 19).

content, that the pollen will be <200 grains per gram—a very low amount. The pollen content is not suitable for study. However, there is a small amount of charred particles that could yield an AMS date. But, I would be skeptical of the 14C results since the organics in the core material have been largely lost via oxidation.

The basic pediment-pedisediment character of the Otero Mesa surface is displayed in Figure 38. The mesa soils are variable in their nature (Derr 1981, Sheets 18, 24, 30), with large areas underlain by Armesa, Lozier, and Philder soils (see Table 2). Most soils have subsoil calcic or petrocalcic horizons, or remnants of them, at all stages of development (biochemical vector) and undevelopment (biomechanical vector). Caliche and bioturbation are the name of the 'process game' on the Mesa.

Insights to the nature of the pediment-pedisediment veneer and to the process vectors that develop and undevelop (destroy) their caliche subsoils are provided by artificially eroded areas, such as those shown in Figure 117 (see also Figure 38); by surface exposures such as those shown in Figures 118, 119, and 120; and by several bulldozed and graded roadbeds on the mesa (Figures 121-123).

The photos in Figures 121-123 were fortuitous in that they were taken shortly after Mesa Road had been graded several kilometers south of Camaleche Tanks. The section of road is just off the far southeastern border of McGregor. The grader had removed about 1 m (3 ft) of the upper in situ soil-pedisediment (regolith) along a stretch of several km. The intact original upper profile is preserved in the bank of the roadbed. The graded roadbed itself is a plan view complement to what was evident in the sidewalls of Sulphur Tank and other backhoe pits described in this report. The roadbed, and the subsurface processes manifested by Figures 116-120, show that a multitude of biomechanical processes (i.e., various animals and roots) operate as a collective ongoing vector that destratifies parent dunes, alluvium, and pedisediment on McGregor such that soil is regularly mixed and the caliche development clocks are episodically reset, as it were. The two graphic models, one that shows the pedogenic role of rodents, mainly gophers, and another that shows the role of rodents and badgers, mainly badgers, are in Figures 124 and 125. The main culprit is shown in Figure 126.

Sacramento Mountains Zone

The Sacramento Mountains portion of McGregor is largely one of exposed bedrock, moderate to steep pedimented surfaces with thin veneers of pedisediment and soil, and ribbons of alluvium in the dissecting drainage channels. They represent an uplifted rock mass, or horst, with structural linkages to the complex Rio Grande rift set of processes. They have been uplifting through time relative to the Tularosa Basin, which has been downdropping. The mapping units are mainly B, P, A1, A2-A3, or some combination of them, such as P/A2-A3 (Bug Scuffle, Culp, El Paso Canyon, Surveyors, and Sixteen Canyon quads).

The major land sculpting processes are erosion, mass movement, and deposition that range across large and small scales. This is an area of normally light snow accumulation in the winter, and occasionally torrential downpours in the summer. The slopes are in general too steep for significant biochemical processes to manifest themselves in soil horizons. The bioturbation processes are shrub and tree root growth, and rodent burrowing. Figure 127 provides two views of the alluvial fill of the Sacramento River and the role of rodents in destratifying formerly imbricated and stratified sediment.

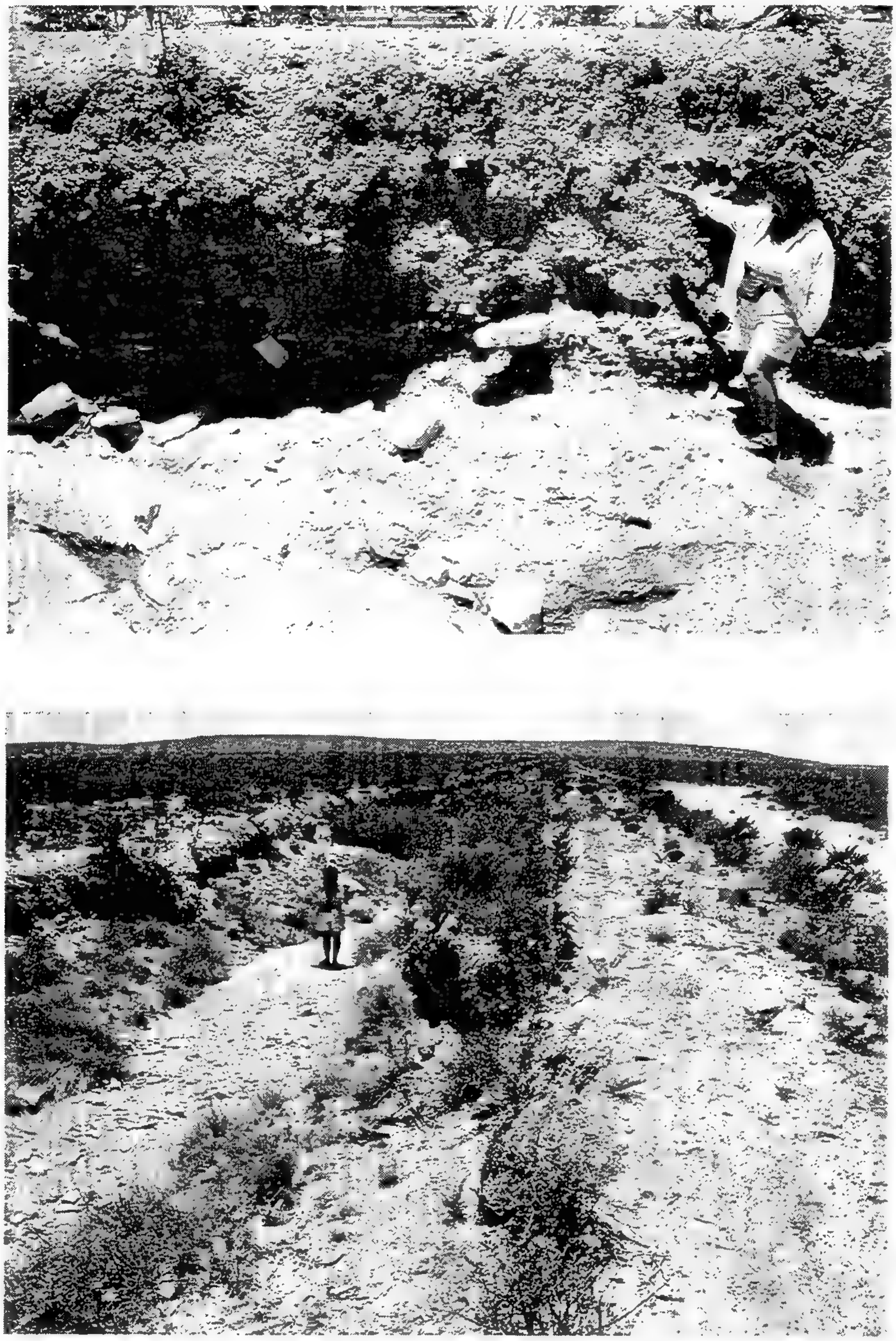


Figure 117. Anthropic-initiated erosion along former north-south road, south of Mesa Horse Camp, northeast corner of Otero Mesa South quad. Photos show the shallow pedimented surface of Otero Mesa. Upper photo shows field assistant D. N. Johnson pointing to boundary between lower stratified gravels and upper randomly oriented gravels of biomantle.

Figure 118. Examples of different types of burrows. Upper photo, ground squirrel mounds that are common all across the mesa. Lower photo, prairie dog mound and burrows near Mesa Horse Camp, Otero Mesa.

Figure 119. Photos show calichefied pebbles (upper) and chunks of petrocalcic horizon (lower) that were gathered from a prairie dog mound near Mesa Horse Camp, Otero Mesa.

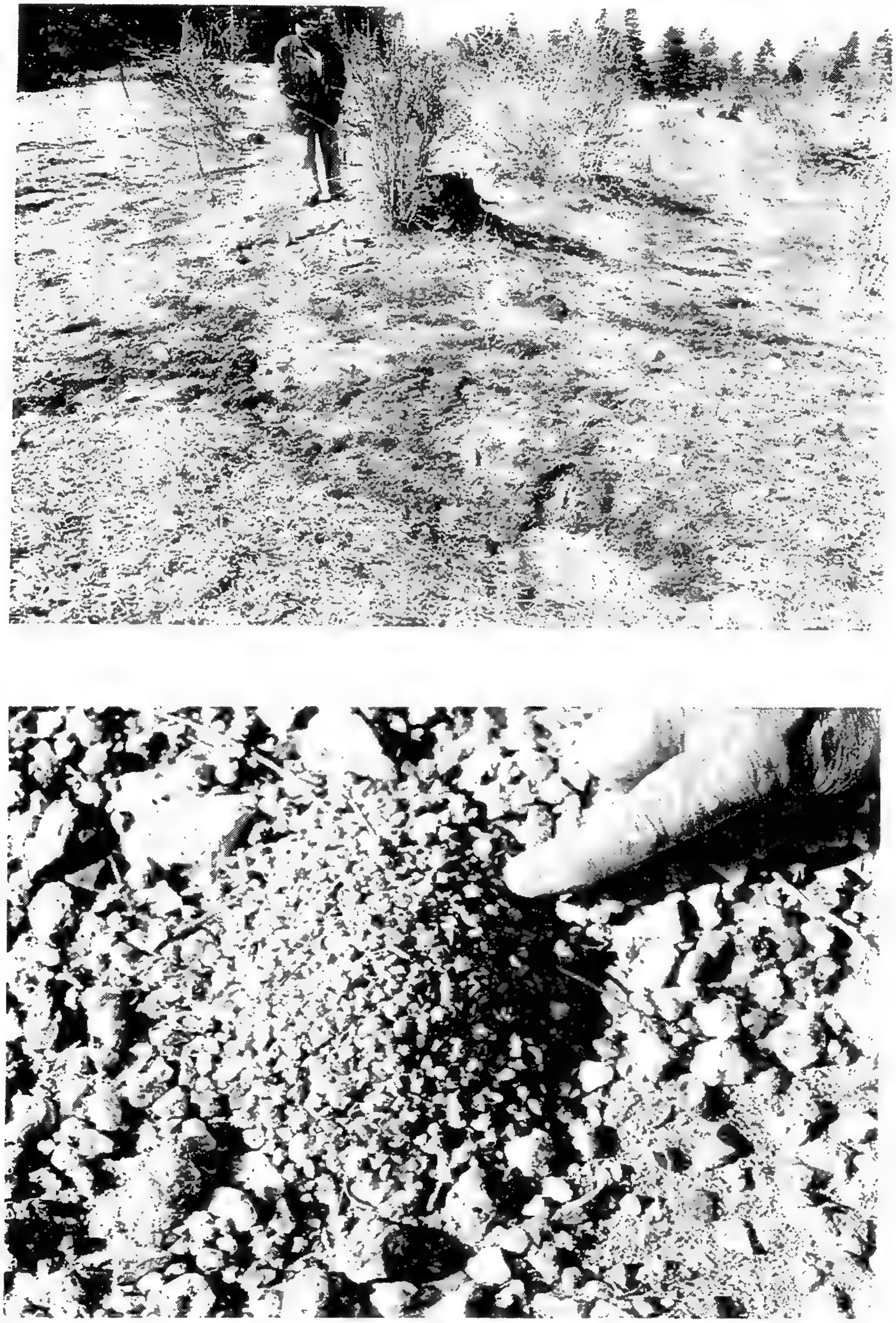


Figure 120. Types of burrows and mounds common on and near McGregor Range, New Mexico. Upper photo, bioturbation created by pocket gopher, produced under snowpack during the winter of 1995-1996, north of the Bug Scuffle Canyon quad (off of McGregor Range). Lower photo: ant mounds on Otero Mesa are ubiquitous and involve many species of ants that produce mounds of different sizes and geometrics with different grain sizes.

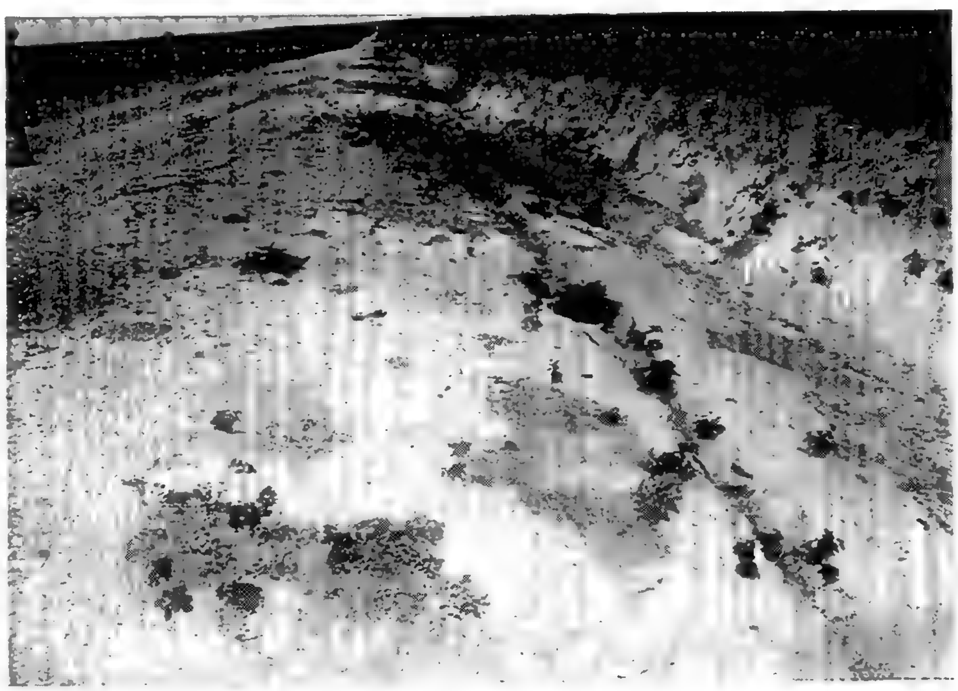


Figure 121. More views of bioturbation by mustelids (badgers) and rodents (prairie dogs, ground squirrels, pocket gophers, kangaroo rats) on Otero Mesa, 2-3 km southwest of Camaleche Tanks, Mountain Tank quad, New Mexico. Upper photo shows how the upper horizon of the soil extends into and fills the burrow. Lower photo is a view NE along the Mesa Road with multiple large-scale krotovina complexes in roadbed where petrocalcic horizon (caliche) has been destroyed and reformed repeatedly. Plants here preferentially grow in the 'krotovinized' areas. In these flattish areas, where slope is not a dominating factor, these views show that biomechanical and biochemical vectors are in constant interaction, with the biochemical vector dominant in some places, and the biomechanical vector dominant in others, with each theater of dominance changing through time.

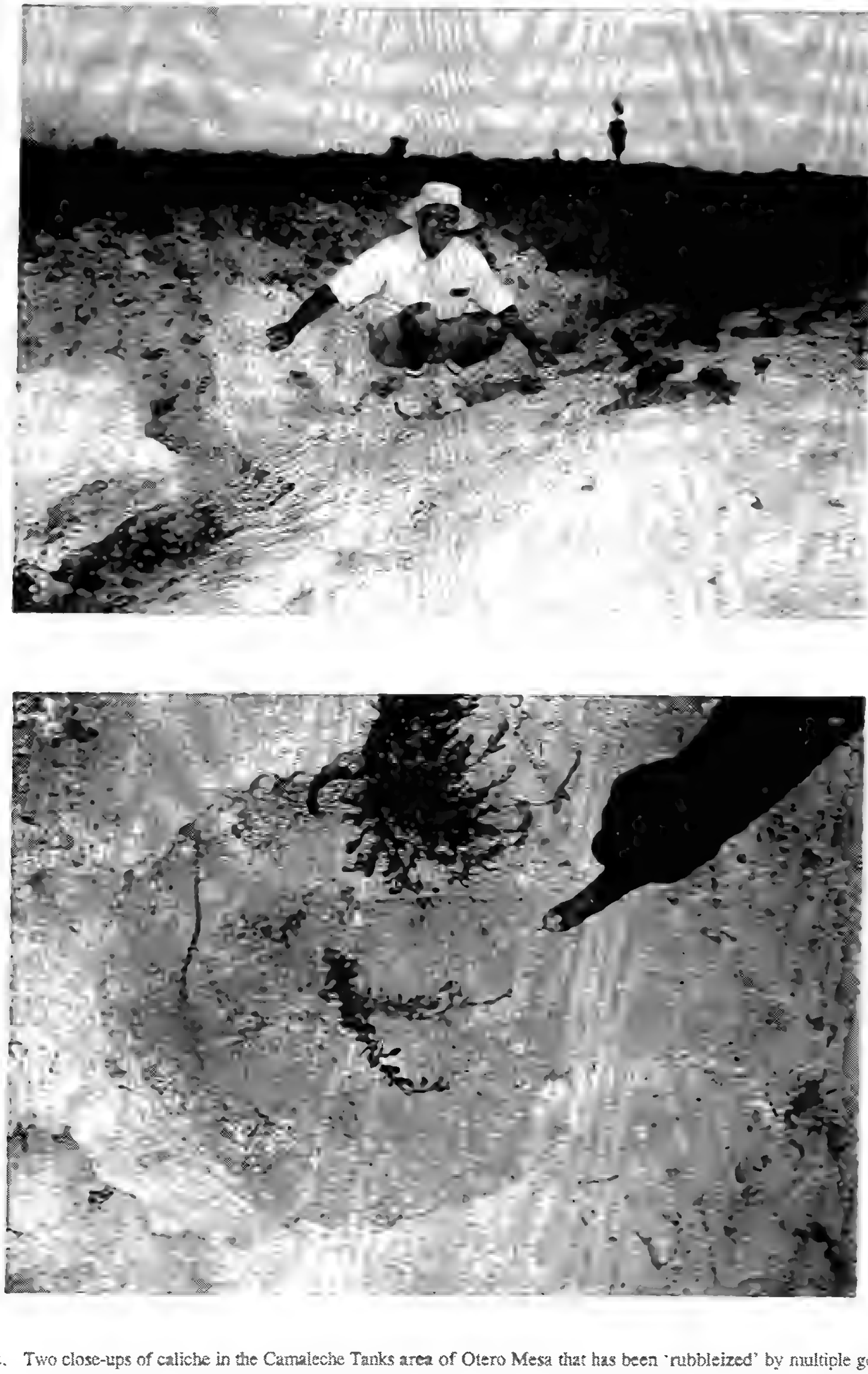


Figure 122. Two close-ups of caliche in the Camaleche Tanks area of Otero Mesa that has been 'rubbleized' by multiple generations of bioturbating vertebrates. Note in upper photo near right hand of author how different-aged krotovinas are confirmed by different degrees of caliche overprints. In lower photo note that 'caliche enrichment' has occurred around burrow perimeters of badger krotovina. Note too the preferential growth of plants in these krotovinized areas.

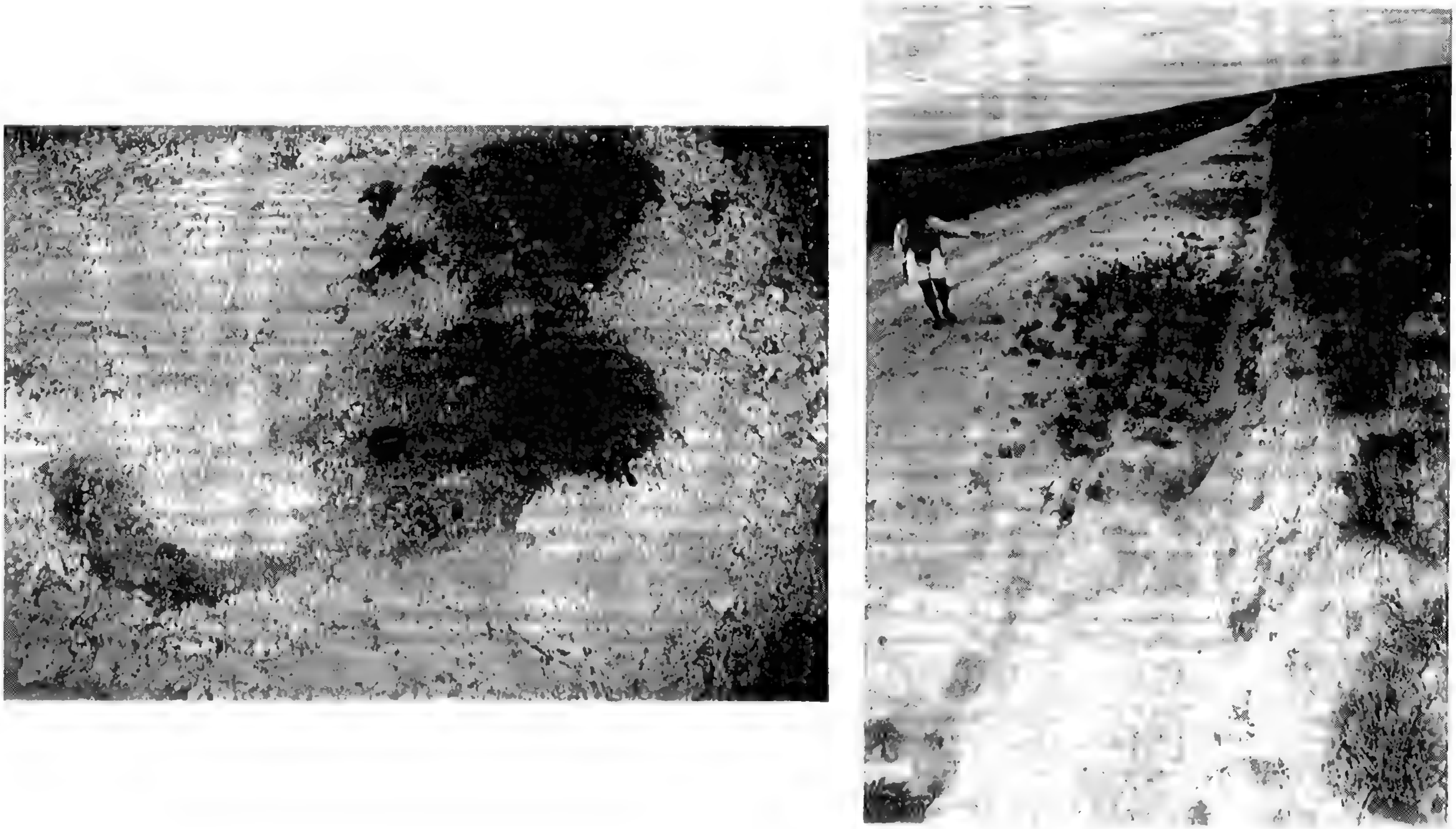


Figure 123. Other views of biochemical-biomechanical interactions along Otero Mesa Road. Right photo, especially, shows examples of the subtle caliche overprinting that is differentially imparted to multiple generations of krotovina, possibly spanning thousands of years (we do not know what timespans are involved). Other exposures along this and other roads suggest that the whole of Otero Mesa probably retains similar biochemical-biomechanical legacies.

Desert Soils - Surfaces:
Calcareous Gravelly Alluvial Fans and Pedisediments

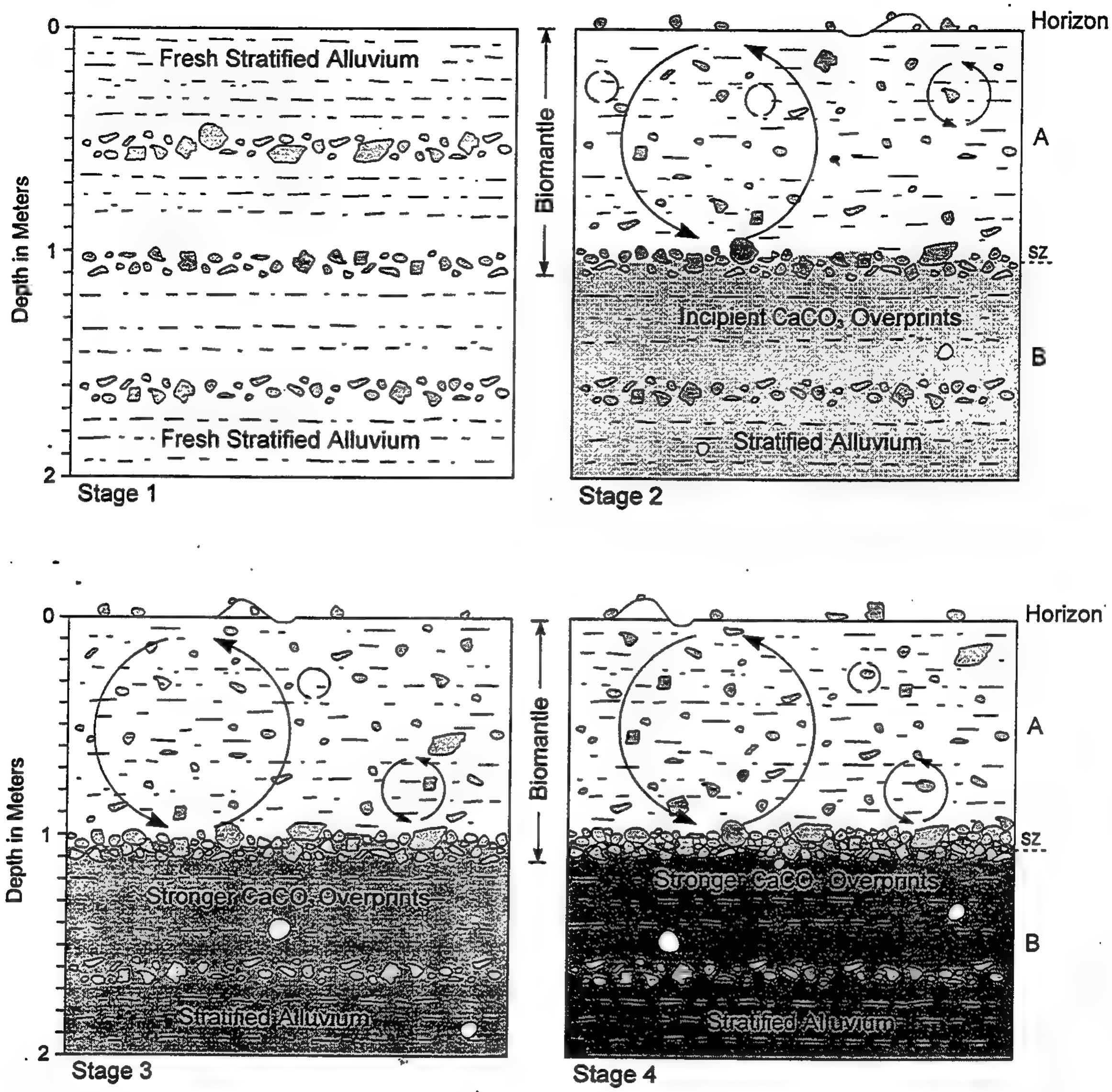
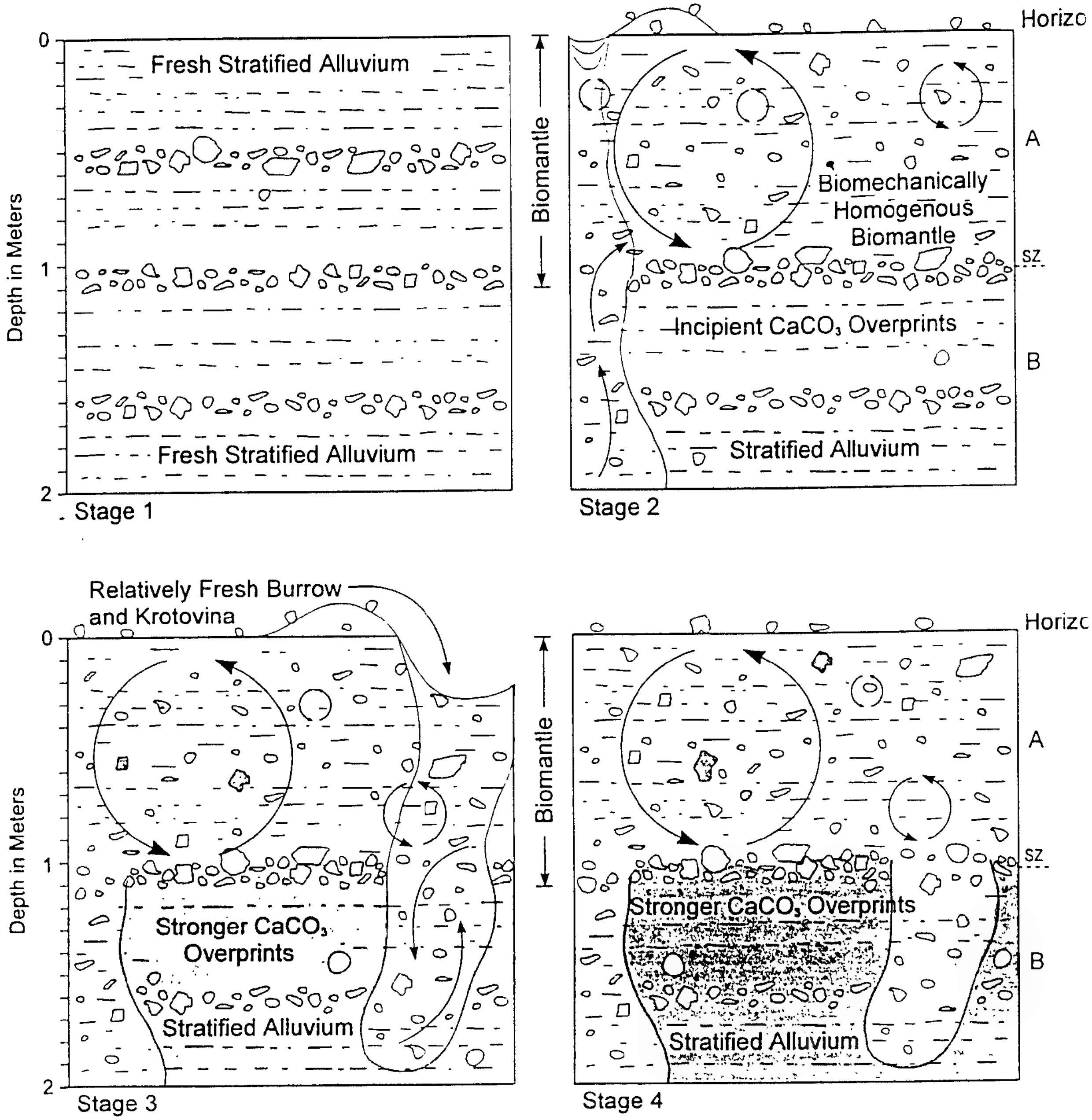


Figure 124. General model of Chihuahuan desert soil formation in gravelly calcareous alluvial fans and pedisediment that emphasizes the two most dominant processes: small mammal and invertebrate *bioturbation* and *pedogenic carbonate overprinting*. In this model bioturbation is via roots of desert plants, and burrowing of invertebrates and small vertebrates. *Stage 1*: Two meters of fresh undisturbed stratified alluvium deposited during one or several penecontemporaneous storms (alluviation-mudflow-debrisflow events). As the pedogenic clock begins ticking at time zero, bioturbation by plant roots and invertebrates (ants, termites, cicadas, wasps, etc.) begins, as indicated by small circular arrows. Small vertebrates also begin bioturbating (gophers, ground squirrels, kangaroo rats, etc.), as indicated by the large circular arrow. Pedogenic carbonate overprinting also commences at this time via bicarbonate-rich wetting fronts and subsequent precipitation of $CaCO_3$. *Stage 2*: Owing to these processes, a biomantle has formed, normally in the upper 0.3-1 m, that includes the topsoil and the beginnings of a coarse clast stone-zone (SZ), coincidentally superimposing onto a previously deposited gravel layer; an incipient calcic horizon also has begun to form as a B horizon, indicated by a slight color darkening. The biomantle, which includes the developing stone-zone, is produced by bioturbation in general, and the stone-zone more specifically by a combination of invertebrates and small vertebrates (large clasts which cannot fit through small burrows sink to form the stone-zone). *Stage 3*: Continued bioturbation and carbonate overprinting. A calcic B horizon is fully formed, and the stone-zone is thicker. *Stage 4*: Continued bioturbation and $CaCO_3$ overprinting; the calcic B horizon is more strongly developed, approaching petrocalcic levels. Note that stone-zone is thicker, and individual clasts and fine fractions in the biomantle have moved about dynamically during stages 2-4. No timeframes are suggested, for rates of processes vary with the site and situation.



Stage 1: Same sediment and processes as in the general model of Figure 124.

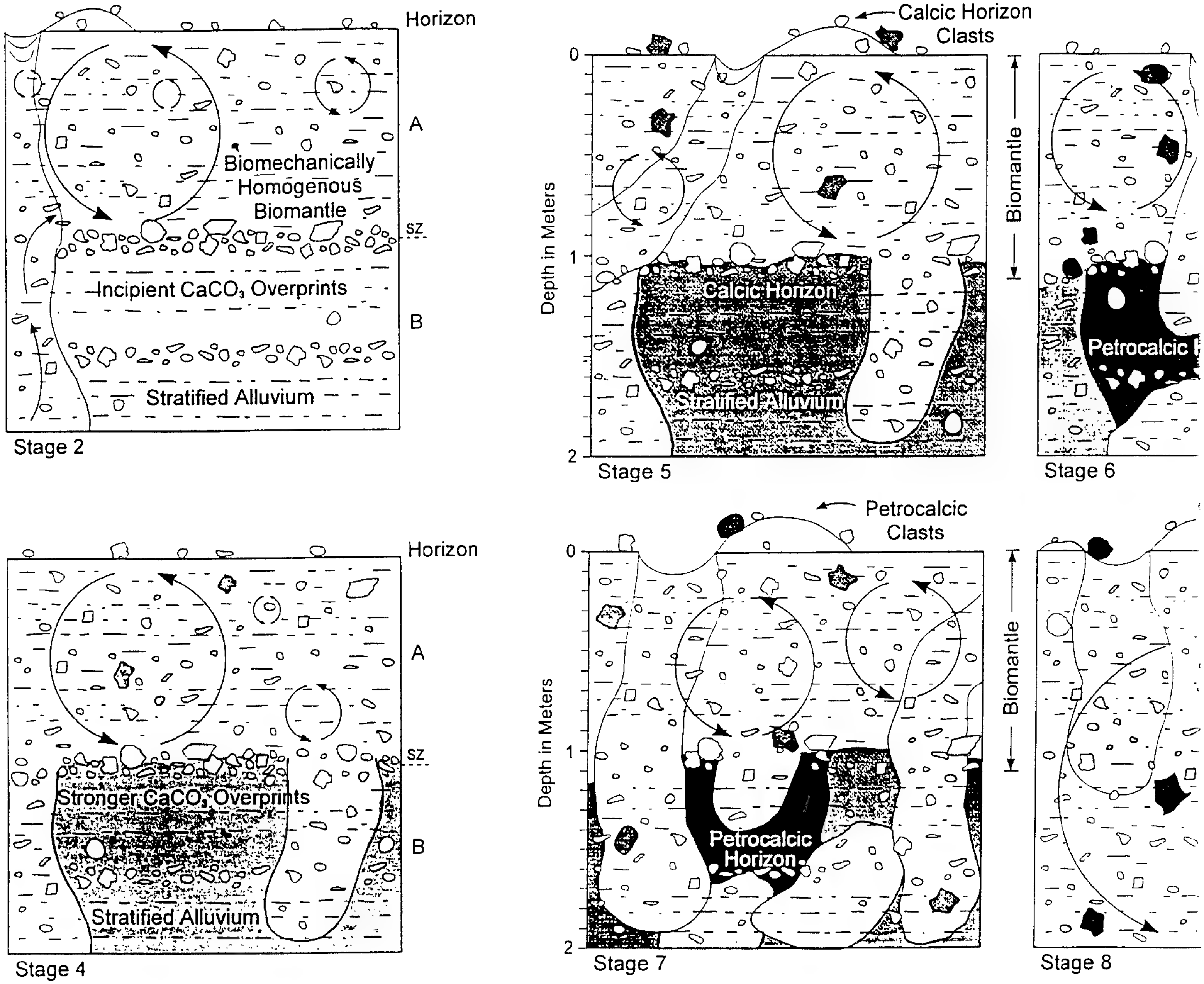
Stage 2: As in the general model, a biomantle has formed, with an incipient stone-zone (SZ) at its base, and an incipient calcic B horizon. But here a badger has burrowed into the left part of this and adjacent pedons. Note that badgers burrow more deeply than small vertebrates and produce far larger krotovina.

Stage 3: Continued bioturbation and carbonate overprinting, including incipient caliche overprints into the now relict badger krotovina; a new badger krotovina appears (right side). Note caliche thickening of old krotovina perimeters, and note that badger bioturbation is slowly destroying the stone-zone and offsetting its formation (most stones are smaller than badger burrows, and thus are recycled by badgers).

Stage 4: Continued bioturbation and CaCO, overprinting; a remnant stone-zone and still-evolving calcic horizon have escaped destruction by badgers.

Figure 125. This version of the model of Chihuahuan desert soil formation is the same as the general model, except that it includes large vertebrates in a Mexico, including the McGregor Range, they are emphasized in the model.

1



.lel of Figure 124.
vith an incipient stone-zone (SZ) at its base, and an incipient calcic
he left part of this and adjacent pedons. Note that badgers burrow
r larger krotovina.
:, including incipient caliche overprints into the now relict badger
ide). Note caliche thickening of old krotovina perimeters, and note
one-zone and offsetting its formation (most stones are smaller than

remnant stone-zone and still-evolving calcic horizon have escaped

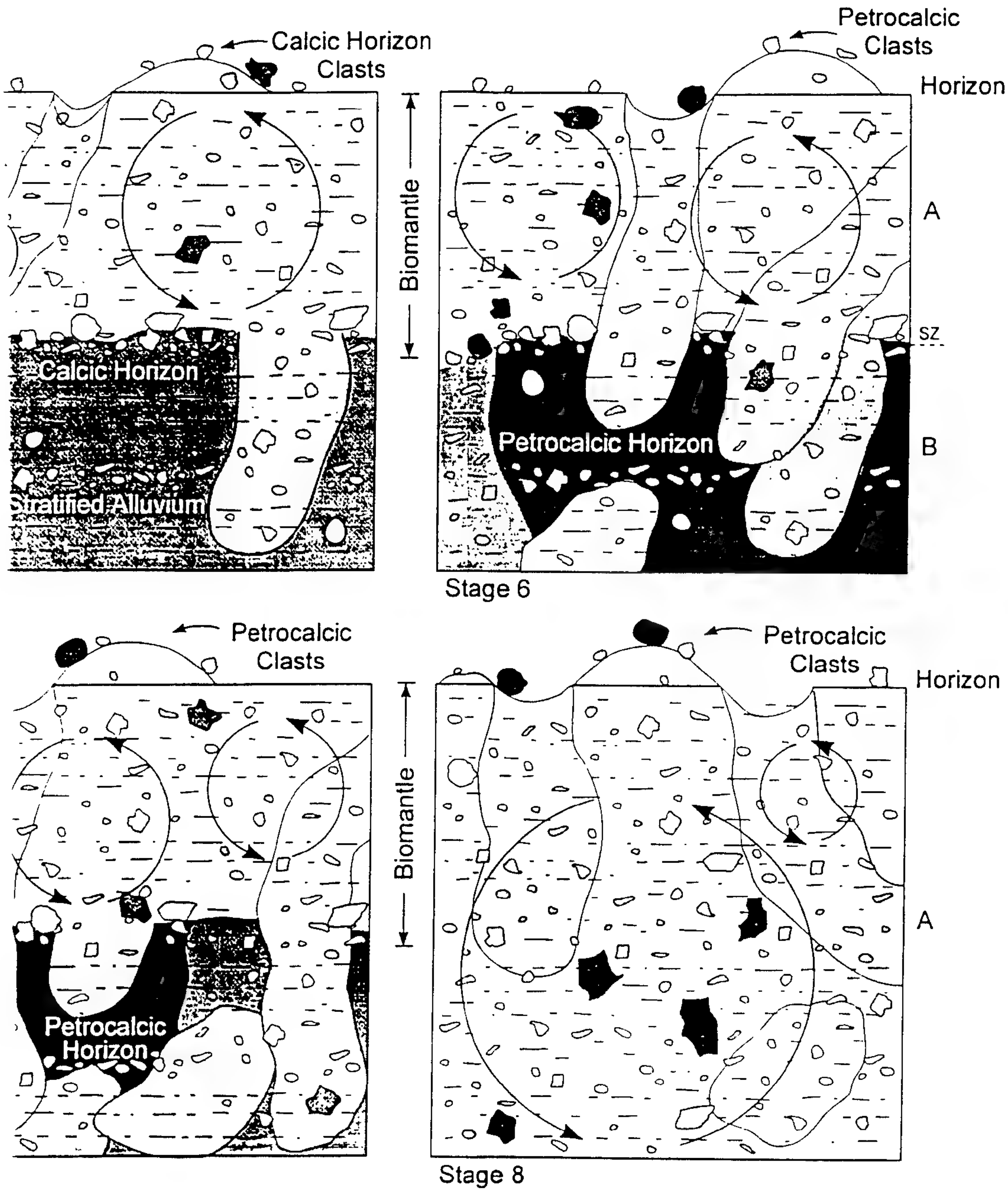
Stage 5: Continued bioturbation and pedogenic carbonate overprinting, with one new badger kı has formed.

Stage 6: Continued bioturbation and $CaCO_3$ overprinting. Petrocalcic horizon is now formed, from below.

Stage 7: Petrocalcic horizon remnant is more developed, but reduced in size. Stone-zone has be

Stage 8: Extreme end member example of a badger-homogenized profile This stage typifies mapping surfaces, for example at Sulphur Tank and Stone School, and on pedisedime Escarpment zones. No timeframes are suggested, for rates of processes vary with the and in reference to Stages 3-7, that in arid and semiarid environments where wetting krotovina of B horizons have longevity as relics, whereas in humid and perhumid en short-lived, becoming overprinted, blurred, and erased over short periods.

same as the general model, except that it includes large vertebrates *in addition* to small vertebrates and invertebrates as bioturbators. Inasmuch as badgers are the most prodigious large model.

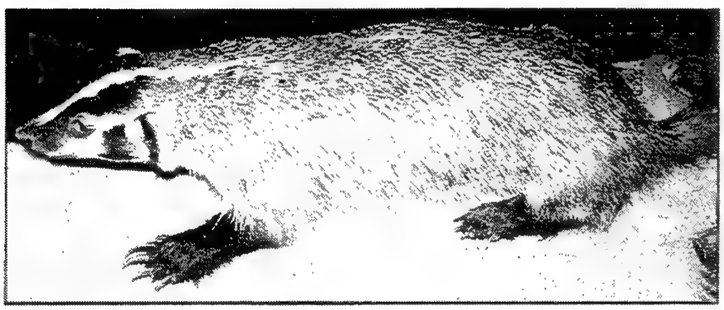


ıed bioturbation and pedogenic carbonate overprinting, with one new badger krotovina (left side). Calcic horizon ·ned.
ıed bioturbation and CaCO, overprinting. Petrocalcic horizon is now formed, into which a badger has burrowed ·low.
lcic horizon remnant is more developed, but reduced in size. Stone-zone has been destroyed by badger burrowing.
: end member example of a badger-homogenized profile. This stage typifies some McGregor pedons on A2-A3 g surfaces, for example at Sulphur Tank and Stone School, and on pedisediments of the Otero Mesa and Broken nent zones. No timeframes are suggested, for rates of processes vary with the site and situation. It is noteworthy, eference to Stages 3-7, that in arid and semiarid environments where wetting fronts are few per unit of time that ıa of B horizons have longevity as relics, whereas in humid and perhumid environments they are ephemeral and ·ed, becoming overprinted, blurred, and erased over short periods.

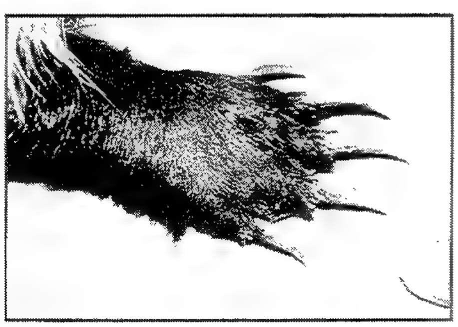
ıvertebrates as bioturbators. Inasmuch as badgers are the most prodigious large burrowers in the desert southwest of North America and

3

Badger (*Taxidea taxus*). Note long--and powerful--front claws.



Side view of badger. Note the size of front claws and low stance. This animal has been called "a remarkable digging machine" (More, 1990).



Claws of badger. Many burrow entrances on McGregor Range show badger claw marks.

Badgers on McGregor Range, TX.

The affects of badgers and other burrowing animals on the soils and landforms of the McGregor Range are profound. The mixing vector in many areas is greater than the organizing vector (see 'Concept of Vector Analysis', Introduction).

Figure 126. *Taxidea taxus*, an important element of the biomechanical vector on the McGregor Range, New Mexico.

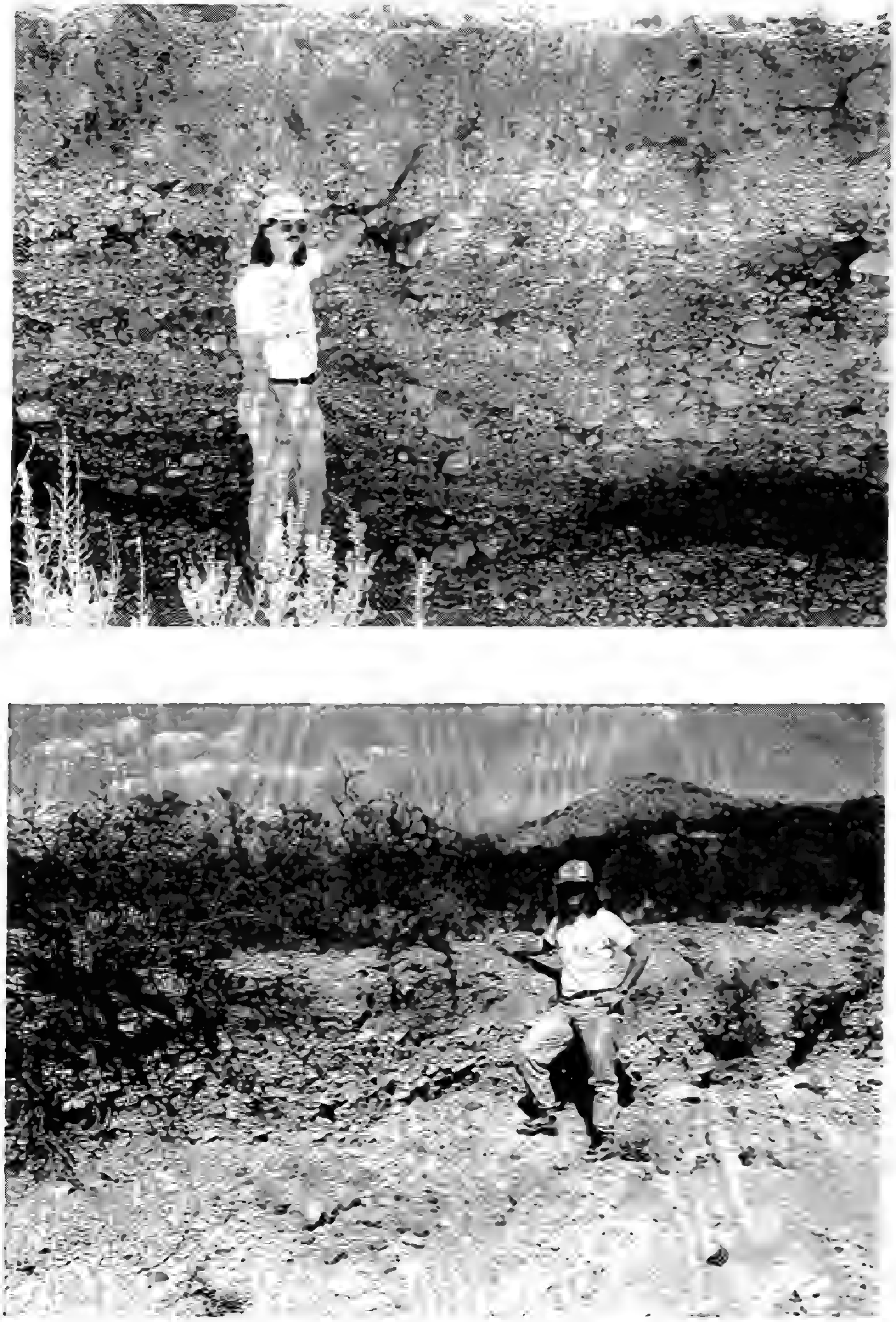


Figure 127. Sacramento River gravels, at the boundary of Sixteen Canyon and Surveyors Canyon quads, McGregor Range, New Mexico. In upper photo, former Directorate of Environment archeologist R. Joe Brandon is pointing to biomantle, the destratified zone above imbricated and stratified river gravels. The boundary between the two layers can be easily discerned in the bottom photo.

CHAPTER 4
CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The major conclusions offered here are in respectful consideration for any long-range planning of natural and cultural resources of McGregor, for general mitigation purposes, and as an intellectual information and resource base.

1. Faulting and associated structural activities have played key roles in the evolution of all major and many minor landforms on the McGregor Range. Not only do they reflect most gross physiographic features of the landscape, they are responsible for many of the individual landforms and for the entire geomorphic grain of the dissected bedrock and pediment terrain between Otero Mesa and the Tularosa Basin. They are in fact responsible for the very origin of the Tularosa Basin and most of the mountains surrounding it.

2. Other than Camp Rice Rio Grande sediments in the Tularosa Basin, and some fan sediment from the Jarilla Mountains, almost all alluvium on the McGregor Range derives from carbonate rocks and is deposited as carbonate-rich sediment. This basic soil parent material is augmented by eolian dust fallout that is enriched in calcite and gypsum. Other things equal, pedogenic caliche forms more quickly in carbonate than in noncarbonate alluvium; for in the latter the sole source of carbonate is eolian dust. Thus, equivalent expressions of caliches in each do not necessarily reflect equivalent rates of caliche formation.

3. Alluvial fans of the McGregor Range are complex units of alluvium, mudflow, and debrisflow deposits, each of which may be partly or wholly imprinted with a soil (or if buried, a paleosol). Soils and paleosols represent long periods of boredom (pedogenesis) whereas alluvial units represent short moments of terror (deposition). The originally imbicated and stratified alluvial sediments are destratified via bioturbation, and vertebrate bioturbators leave a legacy of dung that can be ^{14}C dated.

4. Except for some playas, almost all the soils and sediments in the five natural zones of McGregor have been bioturbated by florae (roots) and by various vertebrate and invertebrate faunae. The principal archeological legacy of this complex set of processes is the potential for blurred or destroyed stratigraphy, and displaced sediment and cultural materials. Such activity is expressed by surface mounds and subsurface burrows and krotovina. Even so, mixing has not been so thorough as to render the soils and sediments unsuitable for geomorphologic, pedologic, and geoarcheologic analysis. Nor has bioturbation rendered some playa sediments (e.g., Lake Tank) unsuitable for magnetic, phytolith, stable isotope, and chronometric studies.

5. Most reddish sand that is concentrated as coppices, dune sheets, and dune piles in the southern Tularosa Basin ultimately derives from early and late Paleozoic Bliss, Abo, and Yeso formation redbeds that are eroding from basin-bordering uplands. A lesser component derives from the eroded A horizons of soils formed in Camp Rice Formation (ancestral Rio Grande) fluvial sediments across the southern Tularosa Basin.

6. Dune sheets, dune piles, and downwind migrating dune trains are concentrated along the eastern side of the southern Tularosa Basin, especially on the McGregor Range, by southwesterly winds. Some have episodically accumulated over late Quaternary time, whereas others are of historic age. All are part of the Tularosa Basin sand cycle, a cycle that has been greatly accelerated since 1885. Sands are gradually removed from the cycle by episodic alluvial burial along, and on, the canyon fans that emanate from the Sacramento Mountains and Broken Escarpment areas.

7. Most coppice dunes in the McGregor Range are genetically linked to recent dune sheets, which are largely derived from eroded A horizons of sandy soils derived upwind from the west and southwest. Most coppicing is historic in age, whereas some dune sheets and dune piles are prehistoric but have been historically reactivated and expanded; coppices poorly stratified or unstratified are mainly of earlier historic origin whereas those well stratified are of recent historic origin; bioturbation is the destratifying vector.

8. Because historic water-diversion schemes (Sacramento River) and well pumping have significantly reduced surface flow and have drawn down water tables, because stock tanks have circumvented the natural recharge of water tables and springs by surface runoff, and because of widespread recent replacements in the Basin of shallow-rooted grasses, oaks, and yucca by deep-rooted phreatophytes (mesquite-creosotebush) since 1885, Otero Mesa and Tularosa Basin in general are now drier and more xeric than before.

9. Paleolakes Jarilla, Sacramento, and Otero have been intermittently present from the late Pleistocene and throughout the Holocene into the historic period. During the Holocene they presumably were more absent than present, but they did episodically form, as they do now. They, along with smaller lakes, formed concomitantly in the many depressions and playas of McGregor, and have played geoecologically important roles in human-wildlife interactions and maintenance over the last 15,000 years.

10. Aside from fault-related processes and manifestations, the most hierarchically important landscape evolving agents (vectors) on the McGregor Range are physical processes (erosion, mass transfer, eolian deflation, and infall), biochemical processes (caliche formation), and biomechanical processes (bioturbation).

RECOMMENDATIONS

A great many worthwhile archeological, ecological, geoarcheological, geomorphological and pedological studies on the McGregor Range could be recommended to enhance existing information bases, and to support long-term resources management strategies. The archeological resources alone are enormous, and would obviously rank high, if not highest, on any prioritized natural resources wish list of things to do. Acknowledging this, the following are offered as priority nonarcheological considerations in any future work on the McGregor Range.

1. A geomorphic and paleoecological study should be done with an initial focus on the geomorphology, palynology, stable isotopes, and the magnetic and phytolith record of Lake Tank, Bassett Lake, and Vertisol playas. Lake Tank especially is a top candidate for such a study; it is nonvertisolic and has proven stratigraphic integrity as well as a ^{14}C datable pollen record (this study). The Lake Tank record will dominantly reflect local inwash from the Hueco Mountains, but may contain a small eolian component. This focus could be later expanded to include a paleoecological analysis on pack rat (Neotoma) middens that may be present in the Hueco Mountains and along the Broken Escarpment. Both records and chronologies would

be augmentive and provide detailed paleoecological records for this key part of the southwest and the northern Chihuahuan desert in particular.

2. Studies should be initiated to shed light on the ecological, pedological, and geoarcheological roles of select animal bioturbators on the McGregor Range, specifically the roles of badgers, rodents (gophers, kangaroo rats, and ground squirrels), and burrowing insects (cicadas, ants, termites, beetles, and wasps). Most archeologists and ecologists are aware that bioturbation plays an important role in the environment and in site formation processes, but understanding and quantifying its effects represent a major challenge. McGregor is a natural laboratory for such studies that are long overdue.

3. As a corollary study to the above numbers 1 and 2, it is recommended that pilot research be initiated to begin age-dating the soils and sediments of McGregor at select sites. Datable materials in the form of fecal pellets, cicada burrow linings, and other organics were observed in a number of backhoe pits, and this study has shown that pollen and fecal pellets can be extracted and dated, even if samples are in small amounts (AMS method). Such studies would be mutually augmentive with those of above numbers 1 and 2.

4. Consideration should be given to a study that would shed light on whether Paleolake Otero was filled maximally to the 3,950-foot level, or to the 4,000-foot-plus level. A first step would be coring the playas of Old Coe and Davies lakes. If salina type alkali lenses and layers are present in the sediments of these latter two playas, they would indicate connections with the originally hypothesized larger, higher, and alkaline Paleolake Otero; their absence would support the more recently hypothesized smaller alkaline Paleolake Otero, with and attendant separate, higher-lying fresh water satellite Paleolakes Coe, Davis, and Jarilla. The justification for such a study is simply an increased understanding of the way the McGregor Range and surrounding areas have evolved to answer the question, how do we know what the environment will do if we do not know what it has done?

5. Because the Ditch Camp area in the Jarilla Bolson Zone has such an abundance of prehistoric cultural materials, which extend into Units 1 and 2 of site 3 (Sand Canyon North, see Figure 33), a detailed stratigraphic and chronometric study of the local pedostratigraphy exposed along this barranca should be conducted. This work can be justified on its own merits, but would be especially justifiable if any archeological work is anticipated for the area.

6. A geologic-geomorphic study of the Culp-Grapevine-Bug Scuffle paleofans should be conducted to ascertain their exact nature, their relative ages, and their relative degrees of pedologic development and dissection. In the case of North and South Culp paleofans, following the points made in the text, it should be ascertained whether relict alluvium is even present.

7. A clay mineralogical study should be conducted to determine why some playas are vertisolic (Vertisol Playa)—and are thus less useful for paleoenvironmental reconstructions—and why some lack vertisolic attributes and thus are more useful (Lake Tank Playa).

8. It is recommended that a geoarcheological study be initiated on several select playas with multiple shorelines (bathtub rings) that have associated hearth and other sites to shed light on the nature of the associations, i.e., Do the sites reflect habitation coincident with different lake levels?

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GLOSSARY

Alkali Lunette: An alkali-rich gypsite lunette dune that forms downwind from an alkali playa, which may be a precipitation-deflation playa. Massive or crystalline gypsum is diagnostic, though calcium carbonate and other precipitates are invariably present as well. The Great Wall of China lunette is an example, and though gypsum dominates, quartz sand is also present. White Sands National Monument is the classic example (cf., *playa, alkali playa, deflational playa, precipitation-deflation playa, solutional playa, temporary playa, gypsite lunette, quartzose lunette*).

Alkali Playa: A playa that receives alkali from storm runoff, and/or which precipitates it on its floor from alkali rich or brackish groundwater (where the latter is the case, ground water may or may not be under an artesian head). In either case, gypsum and carbonate are usually dominant salts that precipitate and effloresce on the playa floor, which wind invariably deflates and deposits as an alkali (gypsite) lunette dune downwind of the playa. Salt Cedar Playa is an example (Orogrande N quad); (cf., *deflation playa, temporary playa, permanent playa, precipitation-deflation playa, solutional playa*).

Alvarado Lake: A lake of variable size immediately north of Three Buttes which forms whenever adjacent playas fill and coalesce. Its size and longevity is determined by the amount of runoff received from the Broken Escarpment area, in 1941 estimated to have filled approximately to the 4,085-foot contour line. Pete Atkins (personal communication 1996) estimated it then to be about one mile across, and recalled it as lasting into 1942.

Biofabric: Soil fabric produced largely by biota (Johnson 1990), which consists of a mix of biochannels, biovoids, biovughs, fecal pellets, and randomly tipped clasts (which may or may not have been originally stratified and/or imbricated).

Biomantle: A differentiated zone in the upper part of soils produced largely by bioturbation but aided by subsidiary processes (Johnson 1990).

Biomechanical agents: Physical (mechanical) disturbance of sediment or soil by biota (Johnson 1993; cf., *bioturbation*).

Biomechanical processes: Physical (mechanical) disturbance of sediment or soil by biota (cf., Johnson 1993; syn., *bioturbation*).

Bioturbation: Sediment and soil disturbance and mixing caused by biota, mainly by animals (faunalturation) and plants (floralturbation) (cf., Hjole 1961; Schäefer 1952; syn., *biomechanical processes,* cf., Johnson 1993). Bioturbation may induce ordered profiles, sometimes with stone-lines (proanisotropic bioturbation), or disordered and homogenized profiles without stone-lines (proisotropic bioturbation), depending on the agents of bioturbation (cf., Johnson et al. 1987).

Bolson: An intermontane basin without a drainage outlet (Peterson 1981). On McGregor an example would be the Jarilla Bolson.

Broken Escarpment: Refers to the broadly eroded area between the Otero Platform and Tularosa Basin floor, especially from Rough Canyon south to the main McGregor Base Camp. Erosion in this area is largely fault-induced, with streams and ridges aligned NW-SE parallel to the direction of faults that break the area.

Broken Escarpment-Hueco Zone: One of five natural geoecological zones of McGregor that encompasses the area between Otero Mesa on the east and the Tularosa Basin on the west, ranging from Rough Canyon on the north to the Hueco Mountains on the south. It includes the Hueco Bedrock Finger, a limestone bedrock outlier on the south side of the Jarilla Gap. They are called natural zones because each has a mix of genetically related landforms and environmental processes and conditions that sets them apart and gives each a distinct geoecological identity.

Coppice Dune: An accumulation of wind deposited sand or sandy soil about the base of an anchoring shrub, like mesquite or creosote bush. In the McGregor Range they are normally associated with and part of a sand sheet (dune sheet). Coppice dunes may be stratified (indicating youth and minimal bioturbation), destratified (indicating extensive bioturbation), or partially destratified. They may be of recent historic, early historic, or prehistoric age. On the McGregor Range they occur almost exclusively in the Tularosa Basin (cf., *dune, dune sheet, dune pile*).

County Road 506: County road name for what used to be called Owen-Prather Road. Also called Mesa Road or Piñon Road by some ranchers. It connects with U.S. 54 at Paxton Crossing. The ancestral horse-and-wagon road ran through Culp Canyon.

Cox Well Playa: The small, gypsum-bearing temporary playa at Cox Well. The playa has accumulated gypsum clay, which has been blown downwind and formed a gypsite lunette on its northeast periphery (cf., *Lee Ranch*).

Deflation Playa: A playa that has experienced deflation and that almost always has an associated wind-deposited lunette on its downwind border. Most playas in the Tularosa Basin are deflation playas. Most playas on Otero Mesa are not, but are solutional playas. A deflation playa may be a temporary playa or a permanent playa. A specialized kind is the precipitation-deflation playa which may or may not accumulate storm runoff (e.g., Lone Butte and Great Wall of China playas, Tres Hermanos quad); (cf., *playa, temporary playa, permanent playa, precipitation-deflation playa, solutional playa, lunette*).

Destratify: A process or set of processes that have operated to destratify originally stratified sediment.

Ditch Camp: Site of Oliver Lee's Thousand Acre Farm on the upper slopes of Grapevine Canyon fan.

Dunal Escarpment: The sand escarpment across which Hwy 54 passes north of Escondido Siding, at mile marker 47. It is a reminder of the thick dune pile over which Hwy 54 passes north of Hwy 506 and south of the Great Wall of China, and exposed in the BLM sand quarry.

Dune: A relatively local, relatively thin (one to several meters thick) individual dune unit that is more or less uncoppiced. It applies best to localized dunes adjacent to, and north and south of, the floor of El Paso Draw on Otero Mesa (cf., *coppice dune, dune sheet, dune pile, lunette, gypsite lunette, quartzose lunette*).

Dune Pile: A thick (several to many meters) pile of dune sand, and/or multiple dunes separated from each another by dunal paleosols. An example is the thick dune sequences which occur intermittently between the BLM site adjacent to Hwy 54 near Escondida Siding and the Sacramento Mountains between Sand and Culp canyons (cf., *coppice dune, dune, dune sheet, lunette, gypsite lunette, quartzose lunette*).

Dune Sheet (syns. *sheet sand, sand sheet*)*:* A dynamic layer of sand of variable thickness, but generally relatively thin, often less than 2 m. Theoretically, it may be as thin as a few centimeters, or even millimeters at its expanding downwind front where it is expressed as saltating grains of sand. It may or may not be coppiced. If coppiced, the dominant anchoring vegetation in the McGregor Range is mesquite, with creosote being subsidiary. If uncoppiced, a yucca-grass association is common. Dune sheets may comprise part or all of a dune pile. Examples are the dune sheets that comprise the dune pile exposed in the BLM borrow pit off Hwy 54 near Escondida Siding, and the dune sheet on the south side of the paved road between Shorad Gate and the bottom of the Jarilla Bolson near Benton Well (cf., *coppice dune, dune, dune pile*).

Escon Hill (syn. *Moody Hill*)*:* The bedrock hill that lies several kilometers west of Highway 54 in the Moody Corrals (Olden ranch) area. The entrance off the highway is the sand borrow pit (BLM site) that is a kilometer or so south of Escondida Siding.

Evaporation-Precipitation-Deflation Playa: A special type of playa that forms when gypsum-rich surface runoff water, or shallow and/or artesian salt-rich ground water, evaporates at the surface, promoting a gypsum- and salt-effloresced puffy soil that is easily deflated by wind. This process, over a long period, removes considerable soil and sediment, causing slow lowering of the playa floor as a gypsite lunette (soil dune) forms from the wind-mined soil on the downwind side (e.g., Cox and Salt Cedar playas, Orogrande N and Wilde Tank quads). Under the right conditions a lobate gypsite soil dune may form and migrate considerable distances downwind of the slowly deepening playa. Examples of such lobate lunettes are in northern McGregor, east of the Great Wall of China Playa and north of the dunal escarpment on Hwy 54 (Tres Hermanos and Deadman Canyon quads); (cf., *alkali playa, deflation playa, temporary playa, permanent playa, solutional playa*).

Faunalmantle: Faunalmantles are biomantles produced largely by burrowing animals (faunalturbation). Faunalmantles may be one-, two-, or multilayered, as differentiated by one or more observable or measurable soil properties. Chief among these properties are particle size and biologically produced soil fabric, or biofabric (Johnson 1990).

Faunalturbation: Sediment-soil disturbance and mixing caused by animals (cf., Johnson 1990; Wood and Johnson 1978; shortened from the longer syn. *faunalpedoturbation* coined by Hole 1961).

Fleck's Home Ranch: (see *McGregor Ranch*).

Floralmantle: Floralmantles are biomantles produced largely by tree uprooting and root growth (floralturbation). Floralmantles may be one-, two-, or multilayered, as differentiated by one or more observable or measurable soil properties. Chief among these properties are particle size and biologically produced soil fabric, or biofabric (Johnson 1990).

Floralturbation: Sediment-soil disturbance and mixing caused by plants (cf., Wood and Johnson 1978, shortened from the longer syn. *floralpedoturbation* coined by Hole 1961).

Great Wall of China Lunette: The large, arcuate gypsite-quartzose lunette that lies immediately west of Highway 54 and north of the Dunal Escarpment at mile marker 47. It forms the eastern boundary of, and is genetically linked to, the Great Wall of China Playa on its west side. A fluvial break-through (Holcomb Channel) and associated delta lie on its extreme southeast side and form a conduit through which storm waters shed from the Sacramento Mountains periodically flood onto the playa floor. Following desiccation, sands washed into the playa by these break-through events saltate to the northeast and accumulate on the Great Wall of China gypsite-calcite-sand lunette. These break-through saltating sands augment sand derived from the reddish coppice dunes on the southwest.

Great Wall of China Playa: The large gypsum-calcite-bearing playa that lies between Lone Butte Playa and Highway 54, immediately north of the Dunal Escarpment at mile marker 47. This playa accumulates gypsum through both the capillary rise of gypsiferious waters from the subsurface and by infusion of gypsiferous sediment from both surface inwash from the Sacramento Mountains and eolian deposition by west-southwest wind to the east-northeast, and which accumulates as a large arcuate gypsite-calcite lunette on its north and east sides. The south and southeast sides of the playa are slowly being buried under reddish coppice dunes blowing in from the west-southwest.

Gypsite: Gypsum-rich sediment, which is usually a mixture of sand, silt, clay, and precipitated $CaSO_4$, $CaCO_3$, and other salts, though dominated by massive or crystalline (selenite) gypsum. The gypsite lunette at Cox Playa is an example (cf., *gypsite lunette*).

Gypsite Lunette: An alkali-gypsum-rich lunette dune on the downwind side of a permanent, temporary, or precipitation-deflation playa. Applies best to Cox and Salt Cedar lunettes in the Jarilla Bolson south of Hwy 506 (Orogrande N and Wilde Tank quads) and the Great Wall of China Lunette (Tres Hermanos quad); (cf., *coppice dune, dune, dune sheet, lunette, gypsite lunette, precipitation-deflation playa, quartzose lunette*).

Gypsite Playa: A playa that receives alkali from storm runoff, and/or which precipitates it on its floor from alkali-rich or brackish ground water (where the latter is the case, ground water may or may not be under an artesian head). In either case, gypsum and carbonate are usually dominant salts that precipitate and effloresce on the playa floor, which wind invariably deflates and deposits as an alkali (gypsite) lunette dune downwind of the playa. Salt Cedar, Lone Butte and Great Wall of China playas are examples (Orogrande N quad); (cf., *deflation playa, temporary playa, permanent playa, precipitation-deflation playa, solutional playa*).

Holcomb Channel: Fluvial break-through channel in the southern end of the Great Wall of China lunette through which floodwaters flow from Holcomb Playa whenever the latter fills with stormwater from Grapevine Canyon. This break-through may have drained high stands of Lake Jarilla into Great Wall of China Playa.

Holcomb Playa: Small playa at the south end of the Great Wall of China Playa, immediately west of Hwy 54 at the Dunal Escarpment.

Hot Well Fault: The more or less NW-SE directed normal fault along which Hot Well occurs, and along which occurs the depression immediately west of the Missile Gate to McGregor Base Camp (Desert SW quad).

Hueco Bedrock Finger: (see *Northwest Hueco Bedrock Finger*).

Hueco Plateau: (see *Otero Mesa*)

Jarilla Bolson (syn. *Jarilla Depression*): Tectonic-structural depression between the Jarilla Mountains and Otero Escarpment in which Benton, Wilde, and Cox wells occur, and in which Benton, Wilde, Salt Cedar, and Cox playas are situated, and which a lake, Lake Jarilla, episodically forms. Its southwestern part forms the *Jarilla Gap* between the Jarilla Mountains and the Hueco Bedrock Finger. (Note: This term and others were earlier applied to the entire Tularosa Basin [Meinzer and Hare 1915]).

Jarilla Bolson Natural Zone: One of five natural geoecological zones of McGregor that encompasses its northwest part, including the normal-faulted Sacramento Mountains escarpment, the Negro Ed-Culp-Grapevine canyons fan complex, the Jarilla Mountains and Jarilla Bolson, Jarilla Gap, and the Otero Escarpment north of Rough Canyon. They are called natural zones because each has a mix of genetically related landforms and environmental processes and conditions that sets them apart and gives each a distinct geoecological identity.

Jarilla Depression: (see *Jarilla Bolson*).

Jarilla Gap: The narrow, structural bedrock gap that forms the SW part of the Jarilla Bolson, situated between the Northwest Hueco Bedrock Finger and the cuestaform limestone outliers of the Jarilla Mountains at Shorad Gate. Trains of slowly NE migrating sand piles occupy its floor (cf., *Jarilla Bolson, North Jarilla-Moody Lowlands).*

Krotovina (or *crotovina*): Originally used by Dokuchaev (1883) for infilled rodent burrows, now often expanded to include any infilled small mammal burrow, and occasionally extended to infilled insect burrows, such as infilled cicada burrows (cf., Sukachev 1902).

Lake Jarilla: Shallow impermanent lake, now usually dry, of variable size that forms periodically during wet years or months, as in 1941. At its maximum it was a large lake that stretched from Wilde Well to Lone Butte during the late Quaternary.

La Mesa Surface: The early-mid Pleistocene surface that bears a thick (>1 m), mainly subsurface laminar caliche-bearing (petrocalcic horizon) soil that is one of the oldest regional surfaces in the Rio Grande Basin. It is visible as a prominent mesa immediately east of the Rio Grande River at Las Cruces (exposed along Interstate 10), extending south to and beyond the U.S.-Mexican border near El Paso. Owing to the presence of river polished gravels that contain obsidian and pumice derived from upper Rio Grande source areas, it has been correlated with the faulted and depressional-hummocky surface in the southern Tularosa Basin and Hueco Bolson, west and south of the Jarilla Mountains (Hwy 54 is on it).

Lee Ranch: Ranch built by Oliver Lee at what is called Cox Well at Cox Playa in this report. Ranch was also owned by the McNew family (cf., map in Meinzer and Hare 1915). The property was flooded in the 1941 storms. Another Lee Ranch occurs on the southern lower slopes of Dog Canyon fan at Oliver Lee State Park.

Lee's Thousand Acre Farm: (see *Ditch Camp*).

Lone Butte Playa: The large gypsum-bearing playa that contains many mini-playas (playettes) and mini-lunettes and which lies immediately south and southeast of Lone Butte, easternmost of the Tres Hermanos Buttes that lie between the Jarilla Mountains and White Sands National Monument. This playa, in which Swope Tank North and Swope Tank South occur, accumulates gypsum clay in numerous small playettes which then accumulates downwind as a large arcuate gypsite ridge-lunette on its north and east sides. It is being encroached upon and slowly buried on its west and south sides by reddish coppice dunes that are moving east-northeast across the Tularosa Basin.

Lunettes: Eolian dunes that form on downwind margins of playas. On the McGregor Range they can be composed of quartzose sand, gypsum (gypsite, $CaSO_4$) and carbonate sediment (calcareous sand, silt, and/or clay), or some combination thereof (cf., Arbogast 1996; Holliday 1997; cf., *coppice dune, dune, dune pile, dune sheet, gypsite lunette, quartzose lunette*).

McGregor Ranch: Ranch one km south of Shorad Gate Blacktop on the west side of the Benton Well-Sulphur Tank Road. Ranch after which McGregor Range was named.

Moody Hill-Moody Corrals: (see *Escon Hill*).

Moody Lowlands (syn. *Moody Windgap*): Lowland sand-clogged area between the northern Jarilla Mountains and Lone Butte, named after Moody Tank. Large volumes of dune sands have migrated through the Moody Lowlands from the southwestern Tularosa Basin to the northern Jarilla Bolson during Quaternary time (cf., *Jarilla Gap*).

Moody Tank: A stock tank in a playa north of the Jarilla Mountains which contains a Folsom site and abundant selenite (gypsum) books (crystals). It is named for the Moody Lowlands, a sand-clogged windgap between the Jarilla Mountains and Lone Butte.

Moody Windgap: (see *Moody Lowlands*).

Newman Faults: The more or less normal, NW-SE directed en echelon faults that occur in the vicinity of Newman on the far SW part of McGregor Range (Newman quad). Hwy 54 and Meyer Range Road pass over the highest, most prominent of the scarps created by these faults.

Northwest Hueco Bedrock Finger (also *Hueco Bedrock Finger*): The ridge or finger of limestone bedrock which extends northwest from the Hueco Mountains almost to the Jarilla Mountains. Only a narrow <2 km wide structural gap, termed here the Jarilla Gap, separates this bedrock finger from the residual limestone bedrock outliers at Shorad Gate.

Otero Escarpment: The generally west-facing escarpment along the Otero Mesa on the eastern side of the Tularosa Basin. The escarpment runs generally N-S between the Sacramento Mountains on the north and the main Hueco Mountains on the south.

Otero Escarpment Faults: The generally north-south directed normal faults near the base of the Otero Escarpment and Sacramento Mountains, along the eastern side of the Tularosa Basin east of the Jarilla Mountains.

Otero Mesa: Tableland that is a northern topographic extension of the Hueco Mountains that lies between them and the Sacramento Mountains to the north. It is underlain by late Paleozoic limestones and redbeds (sandstone-shales-paleosols) of the Yeso and San Andres formations. Also called *Otero Platform, Hueco Plateau,* and *Diablo Mesa* (Black 1973; Hawley 1992; Herrick and Davis 1965).

Otero Mesa Zone: One of five natural geoecological zones of McGregor Range that encompasses the tablelands east of the Otero Escarpment, ranging from the Hueco Mountains on the south to the foothills of the Sacramento Mountains on the north. They are called natural zones because each has a mix of genetically related landforms and environmental processes and conditions that sets them apart and gives each a distinct geoecological identity.

Owen-Prather Road: (see *County Road 506*).

Pediment: As defined in this study, a gently sloping solutional- and/or abrasional- (erosional) bedrock surface over which lies at the foot of a receding hill which may be bare or veneered by a mantle of soil and/or sediment (pedisediment). Pediments may occur on uplands (e.g., Otero Mesa), on escarpments, and/or on escarpment footslopes.

Pedisediment: A thin surficial veneer (~1-3 m) of sediment, either soil and/or alluvium, over a solutionally and/or abrasionally eroded bedrock surface or pediment. The surficial pedisediment on McGregor Range pediments often ranges from 1 to 3 m thick, and is almost always calcareous (McGregor bedrock is mainly limestone, with interbedded, commonly calcareous sandstones and shales).

Permanent playa: A playa normally in the lowest part of the local or regional landscape into which storm runoff water ultimately collects, and which stays until it evaporates or slowly drains downward, or both. On McGregor Range, permanent playas may receive water from upslope temporary playas during great-storm periods. Examples of permanent playas are Lake Lucero, Lone Butte Playa (Tres Hermanos quad), Salt Cedar Playa (Orogrande N quad), Sacramento River (John O. [Stevens] Flat) Playa (Cleones Tank quad), and Bassett Lake (Bassett Lake quad). Bassett Lake is an upland solutional playa on Otero Mesa (on which are many solutional playas and sinkholes), whereas the others are lowland playas in the Tularosa Basin (cf., *playa, deflation playa, precipitation-deflation playa, solutional playa, temporary playa*).

Petrocalcic horizon: A dense, massive or platy carbonate-cemented, continuous caliche layer that cannot be penetrated by a spade when dry; its upper surface often displays cemented plates and/or layers of caliche that are banded and/or lamellae-like; dry fragments do not slake in water (cf., Buol et al. 1989; Gile 1994a).

Playa: Normally a low-lying area in which episodic runoff water accumulates during storm periods to create ephemeral ponds or lakes (see text for formal definition). Playas are either *temporary* or *permanent*. They often, though not always, contain fine-textured, lacustrine sediment. Seven genetic types are recognized on McGregor Range: *solutional, deflation, dune-dammed, dunal, evaporation-precipitation-deflation, faultline, and porous (leak through) playas*. See text for explication (cf., *deflation playa, temporary playa, permanent playa, evaporation-precipitation-deflation playa, solutional playa*).

Prather Playa: A shallow, temporary playa in El Paso Draw where Mesa Road crosses El Paso Draw, 3.5 miles south-southwest of Prather Ranch (El Paso Draw quad).

Prospect Butte: The low, limestone fourth butte of the Tres Hermanos Buttes, which lie between the Jarilla Mountains and White Sands National Monument. So-named for the limestone prospects on its flanks, and the gypsite prospect (for agricultural gypsum) nearby.

Quartzose Lunette: A quartz sand-rich lunette dune on the downwind side of a playa. Applies best to Benton Well Sand Playa on the floor of the Jarilla Bolson north of the Shorad Gate Blacktop. While quartz sand dominates, alkali elements may also be present (cf., *coppice dune, dune, dune sheet, lunette, gypsite lunette)*.

Runon: Refers to water that accumulates in a playa or depression during storms. *Runoff* is water shed from an area whereas *runon* is where that water accumulates.

Sacramento Mountains Zone: One of five natural geoecological zones of McGregor that encompasses the southern part of the Sacramento Mountains. They are called natural zones because each has a mix of genetically related landforms and environmental processes and conditions that sets them apart and gives each a distinct geoecological identity.

Sacramento River Playa: Permanent playa (except during pluvial periods) at the distal end of the Sacramento fan-delta where Chatfield Wash debouches, on the Cleones Tank quad. It is also called the John O. (Stevens) Flat, part of the La Heeta Harvey (Stevens) Ranch. During the last pluvial (12,000-20,000 years ago) it held a lake 130 ft deep (40 m) and 30 square miles (78 km^2) in area, which overflowed to the southeast.

Salt Cedar Playa: The gypsum-carbonate-bearing, permanent precipitation-deflation playa that lies in the lowest part of the Jarilla Bolson, about 2 km southeast of Cox Well, south of Hwy 506. The playa accumulates gypsum- and carbonate-rich sediment via runoff water, which ponds there and evaporates. After evaporation, a gypsite- and carbonate-rich soil efflorescence forms, which the wind deflates and deposits downwind, eventually forming a gypsite lunette along the NNE side of the playa.

Sand Sheet: (see *Dune Sheet*).

Sheet Sand: (see *Dune Sheet*).

Shorad Gate: The guarded gate on the McGregor Range just east of the railroad tracks at Orogrande, NM.

Snail Playa: Circular playa north of Three Buttes that contains (in 1996) aquatic snail shells on its surface and retains evidence of multiple shorelines around its periphery.

Soil Fabric: The arrangement of soil elements and constituents as observed in hand-held specimens, or microscopically in a thin section (peds, biochannels, biovughs, fecal pellets, cutanic bits, biochemical entities, etc.).

Soil Horizons (*Horizons*, *Master Horizons*):

A Horizon:	normally organic-enriched topsoil.
B Horizon:	normally clay and/or calcium carbonate-enriched or chemically altered subsoil.
C Horizon:	parent material for soil.
AB Horizon:	transitional horizon, but more like A than B.

BA Horizon: transitional horizon, but more like B than A.
BC Horizon: transitional horizon, but more like B than C.
CB Horizon: transitional horizon, but more like C than B.
Horizon Notations:

- *m:* Cemented layer (e.g., Bkm).
- *k:* Presence of visible caliche ($CaCO_3$; e.g., Bk, Ck; in this report also used with A, e.g., Ak).
- *p:* Plow layer (e.g., Ap).
- *t:* Presence of illuvial clay (e.g., Bt).
- *w:* Slightly changed (chemically or physically) horizon.
- *y:* Presence of gypsum (e.g., By).

Solutional Playa: A playa formed by solutional weathering of limestone or other soluble rock (e.g., gypsum). Solutional playas may grade into sinkholes and are viewed as elements of karst topography by geomorphologists. Most of the playas on Otero Mesa are of this type, including Bassett Lake, and most lack downwind bordering lunettes (see *deflation playa, temporary playa, permanent playa, precipitation-deflation playa*).

Slopes: Slope terminology used in this report adapted largely from Peterson (1981). It includes landform elements that range from flattish upland surfaces to lowest lowland positions. The main elements are: summit, shoulder, upperslope, midslope, and lowerslope. The lowerslope element may be divided into two sub-elements, footslope and toeslope. Beyond summit slope segments may be subdivided into lower shoulder, upper midslope, upper footslope, middle footslope, lower footslope, and so on.

Stone-line: A stone-line is a three-dimensional (carpetlike) subsurface, single layer of stones in soil produced largely via bioturbation. In a trench or gully it appears as a two-dimensional layer or line of stones, hence the expression 'stone-line.' Sometimes loosely used as a synonym with 'stone-zone' (cf., Johnson 1989, 1990).

Stone-zone: A stone-zone is a three-dimensional (carpet-like) subsurface layer of stones more than one stone thick produced largely via bioturbation. In a trench or gully it appears as a two-dimensional layer or line of stones, hence the expression 'stone-line.' Sometimes loosely used as a synonym with stone-line (cf., Johnson 1989, 1990).

Swift Ranch: An old McGregor Range ranch that was located several km NE of Newman and east of Hwy 54 (Meinzer and Hare 1915).

Swope Tank N: Tank in northern part of Lone Butte Playa (called Squaw Tank on Tres Hermanos quad).

Swope Tank S: Tank in southern part of Lone Butte Playa (called Desert Tank on Tres Hermanos quad).

Temporary Playa: A flattish or low slope surface, often dune-dammed, on which water is temporarily stored during storm periods. During great storms water may overtop the dams and flow to another temporary playa, or even lower permanent playa. Examples are Benton Well and Wilde Well playas (Orogrande N quad) and Prather Playa (El Paso Draw quad), (cf., *playa, permanent playa*).

Thalweg: The lowest part of a stream channel or linear depression. An example would be the grassy, lowest part of El Paso Draw where water collects and drains to the ESE, ultimately to John O. (Stevens) Flats during great storms.

Tres Hermanos: Three buttes (actually four) that lie north of the Jarilla Mountains and between Highways 70 and 54. They are surrounded by gypsite land and adjacent to several precipitation playas and spring mounds. The two westernmost are called Twin Buttes (formerly Two Buttes) composed of late Paleozoic carbonate and redbed rocks, and the easternmost is called Lone Butte (formerly One Butte) composed of an early-mid Tertiary igneous pluton.

Tularosa Basin: A 120-mile long, 35-mile wide graben down-dropped by normal faults that lies between the Organ-San Andres mountains on the west, and the Hueco-Otero Mesa-Sacramento-Sierra Blanca mountains on the east. Its north-south extent is from the Chupadera Mesa on the north to the New Mexico-Texas line on the south. Also called the Tularosa Valley.

Tularosa Basin Natural Zone: One of five natural geoecological zones of McGregor that encompasses the southwestern part of McGregor Range, including the portion underlain by ancient Rio Grande (Camp Rice) fluvial sediments and the toeslopes of fans that onlap onto it from the east.

Venturi Effect: A meteorological condition whereby wind is funneled with higher than average velocity through a mountain pass or particular wind-channeling area of the landscape. Typifies the sand pile accumulation area on the Sand and Culp canyons fanhead area of the southwestern Sacramento Mountains.

APPENDIX A

RADIOCARBON AND POLLEN DATA

RADIOCARBON DATA

Mean Residency Time Soil Organic Matter Radiocarbon Dates

A total of four mean residency time (MRT) radiocarbon dates was run on soil organic matter (SOM) from McGregor area soils and sediments. Technically, the material dated was colloidal organic carbon, but by convention it is referred to as SOM. When charcoal or other datable materials are lacking in soils, as is common on the McGregor Range, SOM is dated for want of other datable material.

Bulk samples taken in the field were pretreated using a method developed by L. R. Follmer at the Illinois State Geological Survey, Urbana-Champaign, IL. Basically, the method involves first air drying the sample, crushing and passing it through a 2-mm sieve, then oven drying and weighing it. The sample is then hydrolized with distilled water (i.e., water is added) and passed through a moderate mesh sieve to remove roots and other macro-organics. A dispersing agent is added (sodium hexametaphosphate) and the sample is then agitated for five minutes in a malt mixer and passed through a very small mesh (63 micron) sieve to further remove macro-organics. The suspension is then acidified to both remove inorganic carbon, namely $CaCO_3$ (calcite) and $CaMgCO_3$ (dolomite) and to effect flocculation of the clay and organic colloidal fraction. The sample is then decanted, resuspended by hand, again acidified, again decanted, filtered, oven-dried, and weighed.

AMS Pollen Dates

Two pollen samples extracted from soil samples at depths of 100-110 cm and 180-190 cm collected at Lake Tank Playa were dated by the AMS (accelerator) method. Dr. Stephen Hall at the University of Texas, Austin, did the pollen extractions, processed them, and generally prepared them for AMS dating in his pollen laboratory. He sent them directly to Beta Analytic.

Inorganic Carbon (Caliche) Dates

Also dated was a caliche ($CaCO_3$) sample from the top of the petrocalcic horizon of a paleosol at 460 cm depth at the BLM Sand Borrow Pit Site, Site 6. It was assumed that the uppermost caliche would have been the last precipitated before the paleosol became buried, and that therefore the date would be meaningful. The sample was leached in 6N HCl, hydrolyzed, then acidified to release CO_2 gas, which was then dated.

Inorganic and Organic Kangaroo Rat Dung Dates

Another inorganic carbon sample ($CaCO_3$) was dated that was extracted from kangaroo rat dung collected at 60-70 cm depth at Dust Pit (Site 40). The organic fraction of this dung was also dated.

Playa Snail Shell (Planorbid) Dates

Dates were also run on the shells of Planorbid snails collected at Vertisol and Snail playas. The shells were surface collected from the playas, crushed so as not to comminute them excessively, then carefully hand cleaned to rid them of soil and non-shell material that might have collected within the shells. The cleaned and washed shells were then quick dipped in 6N HCl to leach away any invisible inorganic calcareous residue that might still have been present after cleaning. They were then acidified to release the CO_2 gas which was dated.

Historic Salsola koli (tumbleweed) Date

A date was also run on the organic carbon of a tumbleweed that lay at the interface of the base of a coppice mound and the soil that it buried. It received the normal pretreatment of all organic carbon dates.

Results and Discussion

The ^{14}C results and associated stable ^{13}C values are given in Table 1. Their significance is discussed at appropriate places in the text, and in the Remarks sections at the end of some of the soil descriptions in Appendix D. Dates are also displayed in some of the profile schematic figures.

POLLEN DATA

Pollen analyses in this study were preliminary only, and were mainly to determine whether pollen was usefully preserved in playa lakes. Several samples from Bassett Lake were sent to Paleo Research Laboratories in Golden, CO (Linda Scott Cummings, Proprietor). Her report, identified as Paleo Research Labs Technical Report 96-27, is attached below. Other samples from Bassett Lake were collected by the author and Dr. Steve Hall, University of Texas, Austin, and were analyzed by Hall in his laboratory. Hall also collected samples at Lake Tank Playa, Vertisol Playa, and the Escondida site. His results are in the form of email correspondence that is also attached below.

NOTICE TO THE SUBMITTER

The information on the reverse side of this form is to be submitted for publication in the journal, RADIOCARBON. Please check to see that all information is correct and complete, and add your comment as to the significance of the date. Your comment should be brief but informative, and should point out why the sample was worth dating. A recent issue of RADIOCARBON may be used as a guide.

If the ISGS has completed a series of age determinations for you from the same locality, use another sheet to give a general comment summarizing the significance of the determinations as a whole. It may be necessary to edit your comment before publication, but any changes which could affect the meaning will be cleared with you.

As there are a great many man-hours that go into determining each date, your careful consideration of the result will be appreciated. If for some reason you would prefer to have this date published without a comment, write "**no comment**" on the form and sign it. **Completed forms should be returned within**
2 weeks to:

Chao-Li Jack Liu
Illinois State Geological Survey
615 East Peabody Drive
Champaign, IL 61820

If you have any questions concerning the date reported or the completion of this form, please feel free to call us.

NOTE: The date reported is a "conventional" radiocarbon date and refers to **Radiocarbon Years** before the reference year A.D. 1950. The date has been corrected for isotopic fractionation, but has not been corrected for the error in the half-life of ^{14}C, or for variations in the atmospheric concentration of ^{14}C. For this reason, the age in Radiocarbon Years may not be exactly equal to the age in solar years, or calendar years. Because use of the B.C.-A.D. time scale implies that the date is in terms of calendar years, **it is urged that the date not be converted to the B.C.-A.D. time scale** until after the above mentioned corrections have been applied.

Ages reported as greater than (>), are minimum ages only. For ages reported as MODERN, the numbers given refer only to the ^{14}C activity of the sample and should not be interpreted as indicating an age in years.

ILLINOIS STATE GEOLOGICAL SURVEY

615 East Peabody Drive
Champaign, IL 61820
(217) 333-4747

REQUEST FOR RADIOCARBON AGE DETERMINATION

(Use separate sheet for each sample and TYPE or PRINT)

Date 11/18 19 96

Name of section or site Dust Pit (Site 40) Carbonate fraction

Your sample number Same site 40 A Weight of sample (dry) ______ gms

Material to be analyzed Rodent (?) droppings (thousands of 'em)

Material from which sample was taken 60-70 cm depth in Soil in Tularosa Valley

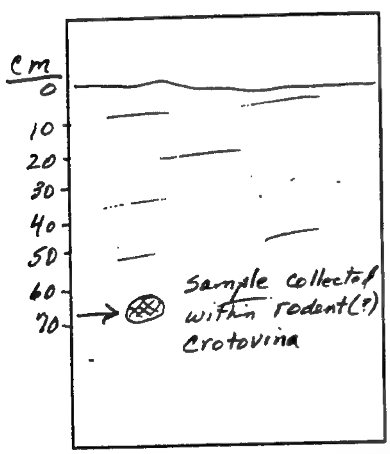
Location: County Otero State NM Country ______

____¼ ____¼ ____¼ Section ____ Township ____ Range ____

____° ____' ____" ____ Latitude, ____° ____' ____" ____ Longitude

Direction and distance (km) from nearest town 10 mi to Orogrande, NM

Stratigraphic unit, position, and thickness, or relationship with cultural materials (make sketch; use metric units) See diagram. Sample was collected from a rodent, probably crotovina (infilled rodent burrow).



Collected by D. L. Johnson Date collected June 9, 19 96

Name and address of person requesting analysis same

Title of project Tularosa Valley Soil geomorph Project

Significance of sample will date crotovina, and shed light on nature of pedogenesis.

Radiocarbon Date Comment Form
Illinois State Geological Survey
615 East Peabody Drive
Champaign, Illinois 61820
Telephone: (217) 244-2192

ISGS-3524

Age: **9200 ± 70 Radiocarbon Years BP** $\delta^{13}C$ = -2.5 per mil PDB

Sample: Dust pit, site 40A

Site: Dust pit, site #40

Material: Carbonate fraction

Location: 16km to Orogrande

County: Otero State: NM Country: U.S.A.

Latitude: 00°00'00" N S Longitude: 00°00'00" E W

Stratigraphic Position:
From soil, 60-70cm below surface

Submitted by: Don Johnson

Submitters Institution: Univ of Illinois

Year collected: 1996 By: D L Johnson

Comment By (initials only): __ __ __
Comment: ____________________

Please check this form for accuracy, fill in any blanks, and return to the ISGS within two weeks (see reverse side for instructions).
January 3, 1997

ILLINOIS STATE GEOLOGICAL SURVEY

615 East Peabody Drive
Champaign, IL 61820
(217) 333-4747

G

REQUEST FOR RADIOCARBON AGE DETERMINATION

(Use separate sheet for each sample and TYPE or PRINT)

Date 11/18 19 96

Name of section or site Dust Pit (Site 40) organic fraction

Your sample number Same Site 40B Weight of sample (dry) ____________ gms

Material to be analyzed Rodent (?) droppings (thousands of 'em)

Material from which sample was taken 60-70 cm depth in Soil in Tularosa Valley

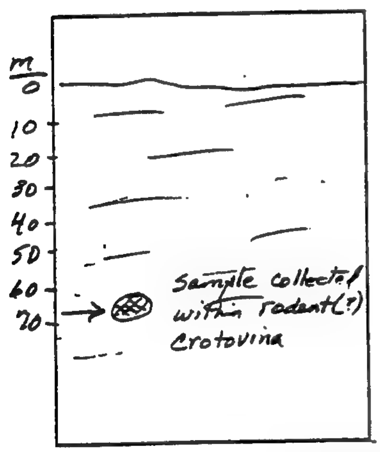
Location: County Otero State NM Country ____________

___¼ ___¼ ___¼ Section _____ Township _____ Range _____

_____° _____' _____" ___ Latitude, _____° _____' _____" ___ Longitude

Direction and distance (km) from nearest town 10 mi to Orogrande, NM

Stratigraphic unit, position, and thickness, or relationship with cultural materials (make sketch; use metric units) See diagram. Sample was collected from a rodent, probably crotovina (infilled rodent burrow).



Collected by D. L. Johnson Date collected June 9, 19 96

Name and address of person requesting analysis same

Title of project Tularosa Valley Soil geomorph Project

Significance of sample will date crotovina, and shed light on nature of pedogenesis.

Radiocarbon Date Comment Form
Illinois State Geological Survey
615 East Peabody Drive
Champaign, Illinois 61820
Telephone: (217) 244-2192

ISGS-3525

Age: **1080 ± 110 Radiocarbon Years BP** $\delta^{13}C$ = -19.8 per mil PDB

Sample: Dust pit, site 40B

Site: Dust pit site 40

Material: Organic fraction of rodent droppings

Location: 16km to Orogrande

County: Otero State: NW Country: U.S.A.

Latitude: 00°00'00" N S Longitude: 00°00'00" E W

Stratigraphic Position:
From soil, 60-70cm below surface

Submitted by: Don Johnson

Submitters Institution: Univ of Illinois

Year collected: 1996 By: D L Johnson

Comment By (initials only): __ __ __
Comment: ______________________________

Please check this form for accuracy, fill in any blanks, and return to the ISGS within two weeks (see reverse side for instructions).
January 3, 1997

ILLINOIS STATE GEOLOGICAL SURVEY

615 East Peabody Drive
Champaign, IL 61820
(217) 333-4747

G

REQUEST FOR RADIOCARBON AGE DETERMINATION

(Use separate sheet for each sample and TYPE or PRINT)

Date 5/28 19 96

Name of section or site Escondida Tank

Your sample number Esc-1 Weight of sample (dry) ______ gms

Material to be analyzed Soil organic carbon

Material from which sample was taken A horizon of buried dunal soil

Location: County Otero State NM Country USA

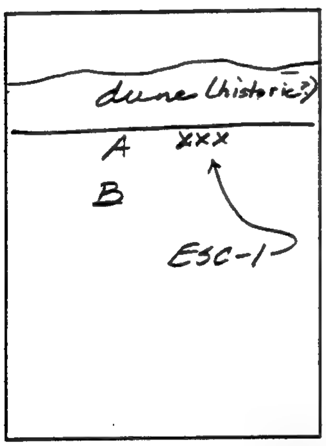
ISGS-3375
790 ± 70

___¼ ___¼ ___¼ Section _____ Township _____ Range _____

_____° _____' _____" __ Latitude, _____° _____' _____" __ Longitude

Direction and distance (km) from nearest town about 3/4 mile east of Escondida Siding, E. side Hwy 54, about 15 mi So. Alamogordo

Stratigraphic unit, position, and thickness, or relationship with cultural materials (make sketch; use metric units) Sample is from the A horizon of a well developed buried soil whose upper part is exposed in a road cut about 100 m. east of Escondida Tank, McGregor Range, Ft Bliss, NM.



Collected by D.L. Johnson Date collected Mar 17, 19 96

Name and address of person requesting analysis Don Johnson

Title of project Tularosa Valley Project

Significance of sample Date will complement BLM-3, sampled about 1.2 miles west; This buried soil is correlated with 2nd buried soil at BLM Caballo Resource Area.

Radiocarbon Date Comment Form
Illinois State Geological Survey
615 East Peabody Drive
Champaign, Illinois 61820
Telephone: (217) 244-2192

ISGS-3375

Age: **790 ± 70 Radiocarbon Years BP** $\delta^{13}C$ = -18.4 per mil PDB

Sample: ESC-1

Site: Escondida Tank

Material: Soil organic carbon

Location: 1.2km E of Escondida Siding

County: Otero State: NM Country: U.S.A.

Latitude: 00°00'00" N S Longitude: 00°00'00" E W

Stratigraphic Position:
From A horizon of buried dunal soil

Submitted by: Donald L Johnson

Submitters Institution: Univ of Illinois

Year collected: 1996 By: D L Johnson

Comment By (initials only): __ __ __
Comment: ____________________

Please check this form for accuracy, fill in any blanks, and return to the ISGS within two weeks (see reverse side for instructions).
June 19, 1996

ILLINOIS STATE GEOLOGICAL SURVEY

615 East Peabody Drive
Champaign, IL 61820
(217) 333-4747

G

REQUEST FOR RADIOCARBON AGE DETERMINATION

(Use separate sheet for each sample and TYPE or PRINT)

Date 5/28 19 96

Name of section or site Old Coe Tank Trail

Your sample number Coe-1 Weight of sample (dry) ______ gms

Material to be analyzed Soil organic carbon

Material from which sample was taken A horizon of La Mesa-like soil buried below under coppice dune

Location: County Otero State NM Country USA

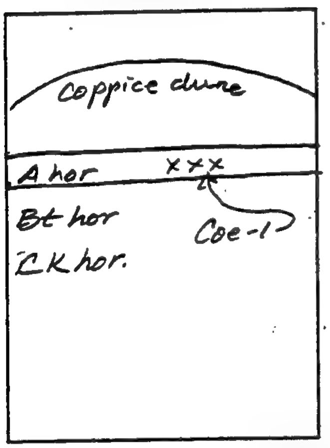
I 565-3377
200 ± 70

___¼ ___¼ ___¼ Section ___ Township ___ Range ___

___° ___' ___" ___ Latitude, ___° ___' ___" ___ Longitude

Direction and distance (km) from nearest town 10 miles south southeast of White Sands Missile Range Headquarters

Stratigraphic unit, position, and thickness, or relationship with cultural materials (make sketch; use metric units) see sketch



Collected by D L Johnson Date collected 1 Oct, 19 95

Name and address of person requesting analysis D. L. Johnson

Title of project Tularosa Valley Project

Significance of sample will give an MRT age of A horizon of Soil buried beneath coppice dunes - a La Mesa-like soil of regional extent.

Radiocarbon Date Comment Form
Illinois State Geological Survey
615 East Peabody Drive
Champaign, Illinois 61820
Telephone: (217) 244-2192

ISGS-3377

Age: **200 ± 70 Radiocarbon Years BP** $\delta^{13}C$ = -21.0 per mil PDB

Sample: Coe-1

Site: Old Coe Tank Trail

Material: Soil organic carbon

Location: 16km SSE of White Sands Missile Range

County: Otero State: NM Country: U.S.A.

Latitude: 00°00'00" N S Longitude: 00°00'00" E W

Stratigraphic Position:
From A horizon

Submitted by: Don L Johnson

Submitters Institution: Univ of Illinois

Year collected: 1995 By: D L Johnson

Comment By (initials only): __ __ __
Comment: ______________________________

Please check this form for accuracy, fill in any blanks, and return to the ISGS within two weeks (see reverse side for instructions).
June 19, 1996

ILLINOIS STATE GEOLOGICAL SURVEY

615 East Peabody Drive
Champaign, IL 61820
(217) 333-4747

G

REQUEST FOR RADIOCARBON AGE DETERMINATION

(Use separate sheet for each sample and TYPE or PRINT)

Date 6/20 1996

Name of section or site Snail Playa

Your sample number Snail Playa #1 Weight of sample (dry) ______ gms

Material to be analyzed Snail shell (Planorbis tenuis) – aquatic species

Material from which sample was taken Same

Location: County Otero State N.M. Country USA

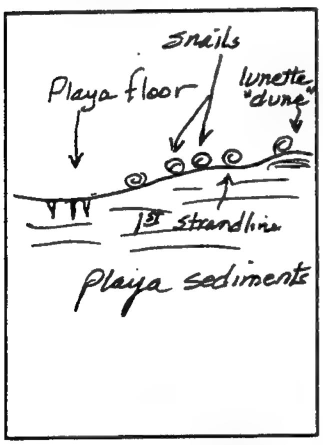
SW ¼ SE ¼ NW ¼ Section 6 Township 25S Range 8E

ISGS-3389
790±80

___ ° ___ ' ___ " ___ Latitude, ___ ° ___ ' ___ " ___ Longitude

Direction and distance (km) from nearest town ~4 Mi No. of McGregor Base Camp, McGregor Range, Ft Bliss, N.M.

Stratigraphic unit, position, and thickness, or relationship with cultural materials (make sketch; use metric units) Snails were lying off the deepest part of playa floor, on basinal perimeter of playa, as well as on 1st strandline about 10' above playa floor. Some also collected from mini-lunette on NE side of 1st strandline.



Collected by Donald L. Johnson Date collected 6/12/96, 1996

Name and address of person requesting analysis Same

Title of project McGregor Range / Tularosa Valley Geologic Mapping Project

Significance of sample If pre-bomb in age, the shells will almost certainly date from 1941-44 when playa had residual water for several years after the big rainfall year of 1941.

ILLINOIS STATE GEOLOGICAL SURVEY G

615 East Peabody Drive
Champaign, IL 61820
(217) 333-4747

REQUEST FOR RADIOCARBON AGE DETERMINATION

(Use separate sheet for each sample and TYPE or PRINT)

Date 5/28 1996

Name of section or site Jobe Sand Quarry

Your sample number JSQ-1 Weight of sample (dry) ______ gms

Material to be analyzed "soil" organic matter

Material from which sample was taken "A" horizon of incipient, dune-intercalated "soil"

Location: County Hudspeth State TX Country USA

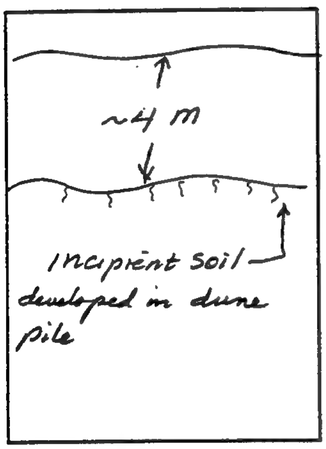
ISGS-3387
210 ± 70

___ ¼ ___ ¼ ___ ¼ Section ___ Township ___ Range ___

___ ° ___ ' ___ " ___ Latitude, ___ ° ___ ' ___ " ___ Longitude

Direction and distance (km) from nearest town outskirts of El Paso, very near Hueco Mtns, E. Montana Ave (½ mile so).

Stratigraphic unit, position, and thickness, or relationship with cultural materials (make sketch; use metric units) See sketch. Sample is from an incipient buried dunal soil



Collected by D.L. Johnson Date collected 9 Oct., 1996

Name and address of person requesting analysis Don Johnson

Title of project Tularosa Valley Project

Significance of sample If date is pre-historic (pre-1850 or so) it will essentially 'prove' that this dune pile was not caused by over-grazing.

Radiocarbon Date Comment Form
Illinois State Geological Survey
615 East Peabody Drive
Champaign, Illinois 61820
Telephone: (217) 244-2192

ISGS-3387

Age: **210 ± 70 Radiocarbon Years BP** $\delta^{13}C$ = -21.2 per mil PDB

Sample: JSQ-1

Site: Jobe sand quarry

Material: Soil organic matter

Location: Outskirts of El Paso

County: Hudspeth State: TX Country: U.S.A.

Latitude: 00°00'00" N S Longitude: 00°00'00" E W

Stratigraphic Position:
From A horizon

Submitted by: Donald L Johnson

Submitters Institution: Univ of Illinois

Year collected: 1996 By: D L Johnson

Comment By (initials only): __ __ __
Comment: ______________________________________

Please check this form for accuracy, fill in any blanks, and return to the ISGS within two weeks (see reverse side for instructions).
July 5, 1996

ILLINOIS STATE GEOLOGICAL SURVEY

615 East Peabody Drive
Champaign, IL 61820
(217) 333-4747

G

REQUEST FOR RADIOCARBON AGE DETERMINATION

(Use separate sheet for each sample and TYPE or PRINT)

Date 6/20 1996

Name of section or site Vertisol Playa #1

Your sample number Same   Weight of sample (dry) ______ gms

Material to be analyzed Snail Shells (Planorbis tenuis) - aquatic species

Material from which sample was taken Same

Location: County Otero   State NM   Country USA

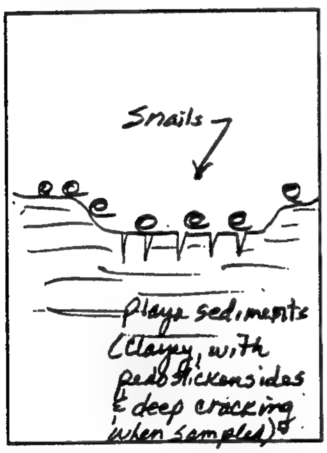
ISGS-3388 Modern, 118 ± 0.6%, ≈ 1985-95 AD.

NE 1/4 NW 1/4 SW 1/4 Section 35 Township 24S Range 7E

___° ___' ___" ___ Latitude, ___° ___' ___" ___ Longitude

Direction and distance (km) from nearest town 15 mi so. of Orogrande, NM just E. of Hwy 54

Stratigraphic unit, position, and thickness, or relationship with cultural materials (make sketch; use metric units) Snail shells lying on playa surface and on lowest strandline, as shown in diagram at left.



Collected by D.L. & D.N. Johnson   Date collected 6/6, 1996

Name and address of person requesting analysis Don Johnson

Title of project McGregor Range / Tularosa Valley Geology mapping project

Significance of sample If pre-bomb in age, they will almost certainly date from 1941-44 (playa had water for several years after the big rainfall year of 1941).

Radiocarbon Date Comment Form
Illinois State Geological Survey
615 East Peabody Drive
Champaign, Illinois 61820
Telephone: (217) 244-2192

ISGS-3389

Age: **790 ± 80 Radiocarbon Years BP** $\delta^{13}C$ = -1.6 per mil PDB

Sample: Snail playa #1

Site: Snail playa

Material: Snail shells

Location: 6.4km N of Mcgregor base camp

County: Otero State: NM Country: U.S.A.

Latitude: 00°00'00" N S Longitude: 00°00'00" E W

Stratigraphic Position:
From deepest part of playa floor

Submitted by: Donald L Johnson

Submitters Institution: Univ of Illinois

Year collected: 1996 By: D L Johnson

Comment By (initials only): __ __ __
Comment:

Please check this form for accuracy, fill in any blanks, and return to the ISGS within two weeks (see reverse side for instructions).
July 6, 1996

G

ILLINOIS STATE GEOLOGICAL SURVEY

615 East Peabody Drive
Champaign, IL 61820
(217) 333-4747

REQUEST FOR RADIOCARBON AGE DETERMINATION

(Use separate sheet for each sample and TYPE or PRINT)

Date 4/12 1996

Name of section or site BLM Caballo Resource Area

Your sample number BLM-1 Weight of sample (dry) ______ gms

Material to be analyzed Salsola (Tumble weed) (Salsola Kali L) Russian Thistle

Material from which sample was taken beneath a coppice dune

Location: County Otero State NM Country USA

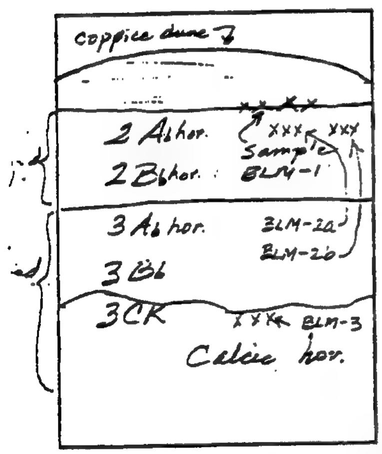
ISGS-3344
134.7 ± 0.6% mod.
$\delta^{13}C$ = -13.9‰ PDB
BLM-1

NW ¼ NW ¼ NW ¼ Section 10 Township 20 S. Range 9E.

___ ° ___ ' ___ " ___ Latitude, ___ ° ___ ' ___ " ___ Longitude

Direction and distance (km) from nearest town 15 m so. of Alamogordo
1.2 km so. of Escondida Siding Hwy 54, W. side highway

Stratigraphic unit, position, and thickness, or relationship with cultural materials (make sketch; use metric units)



This tumble weed is an introduced species from Europe. It is important to learn whether it is pre- or post- atom bomb (pre-post 1945) which will be determined by the C-14 date. If it is post-bomb it will indicate that this coppice dune formed since 1945; if it is pre-bomb, the dune formed before 1945, but after this Salsola was introduced.

Collected by Don Johnson Date collected March 17, 1996

Name and address of person requesting analysis Don Johnson, 713 So. Lynn St.
Champaign, IL

Title of project Tularosa Valley project

Significance of sample see explanation above (the time of coppice dune formation is contentious).

Radiocarbon Date Comment Form
Illinois State Geological Survey
615 East Peabody Drive
Champaign, Illinois 61820
Telephone: (217) 244-2192

ISGS-3344

Age: **113.4 ± 0.6% modern** $\delta^{13}C$ = -13.9 per mil PDB

Sample: BLM-1

Site: BLM Caballo resource area

Material: Weed (Salsola)

Location: 1.2km S of Escondida Siding

County: Otero State: NM Country: U.S.A.

Latitude: 00°00'00" N S Longitude: 00°00'00" E W

Stratigraphic Position:
From beneath a coppice dune

Submitted by: Don Johnson

Submitters Institution: Univ of Illinois

Year collected: 1996 By: Don Johnson

Comment By (initials only): __ __ __
Comment: ____________________

Please check this form for accuracy, fill in any blanks, and return to the ISGS within two weeks (see reverse side for instructions).
April 16, 1996

ILLINOIS STATE GEOLOGICAL SURVEY

G

615 East Peabody Drive
Champaign, IL 61820
(217) 333-4747

REQUEST FOR RADIOCARBON AGE DETERMINATION

(Use separate sheet for each sample and TYPE or PRINT)

Date 5/28 1996

Name of section or site BLM-Caballo Resource Area

Your sample number BLM-2b Weight of sample (dry) ____________ gms

Material to be analyzed Clay-OM sample from A horizon of buried soil

Material from which sample was taken A horizon, buried soil

Location: County Otero State N.M Country USA

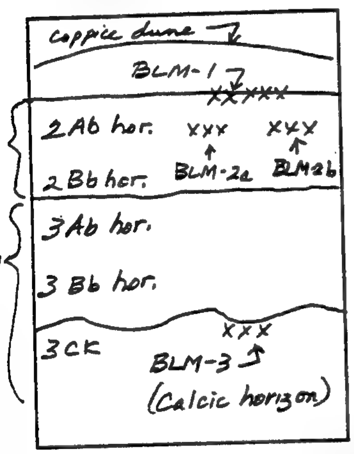
ISGS-3382
670±90

NW¼ NW¼ NW¼ Section 10 Township 20S Range 9E

____° ____' ____" __ Latitude, ____° ____' ____" __ Longitude

Direction and distance (km) from nearest town 15 mi so. of Alamogordo, NM on W side Hwy 54.

Stratigraphic unit, position, and thickness, or relationship with cultural materials (make sketch; use metric units) This sample consists of soil organic matter (colloidal fraction) plus clay. It will give an MRT date, and will complement BLM-2a, which consists of small bits of organic matter dispersed throughout the 2Ab horizon. This date will also complement dates on BLM-1, BLM-3.



Collected by D. L. Johnson Date collected Mar. 17, 1996

Name and address of person requesting analysis D.L. Johnson

Title of project Tularosa Valley Project

Significance of sample will help establish the mean minimum age of 1st buried soil, and the non-coppiced dune sheet that buries an older dune sheet that has a La Mesa-like paleosol developed in it (2nd buried soil).

Radiocarbon Date Comment Form
Illinois State Geological Survey
615 East Peabody Drive
Champaign, Illinois 61820
Telephone: (217) 244-2192

ISGS-3382

Age: **670 ± 90 Radiocarbon Years BP** $\delta^{13}C$ = -19.3 per mil PDB

Sample: BLM-2b

Site: BLM-Caballo Resource Area

Material: Burial soil

Location: 24km S of Alamogordo

County: Otero State: NM Country: U.S.A.

Latitude: 00°00'00" N S Longitude: 00°00'00" E W

Stratigraphic Position:
From A horizon of burial soil

Submitted by: Don Johnson

Submitters Institution: Univ of Illinois

Year collected: 1996 By: D L Johnson

Comment By (initials only): __ __ __
Comment: ____

Please check this form for accuracy, fill in any blanks, and return to the ISGS within two weeks (see reverse side for instructions).
July 5, 1996

ILLINOIS STATE GEOLOGICAL SURVEY

615 East Peabody Drive
Champaign, IL 61820
(217) 333-4747

ISGS-3348
11,710 ± 110 RCYBP
$\delta^{13}C = -3.9$/mil PDB
BLM-3

REQUEST FOR RADIOCARBON AGE DETERMINATION

(Use separate sheet for each sample and TYPE or PRINT)

Date 4/12 19 96

Name of section or site BLM - Caballo Resource Area

Your sample number BLM-3 Weight of sample (dry) ______ gms

Material to be analyzed Caliche ($CaCO_3$)

Material from which sample was taken buried soil (1st)

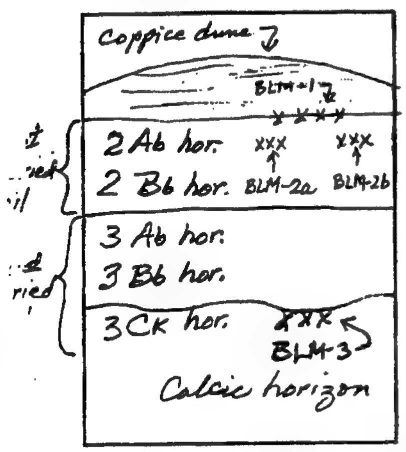
Location: County Otero State NM Country USA

NW¼ NW¼ NW¼ Section 10 Township 20 S. Range 9E.

____° ____' ____" __ Latitude, ____° ____' ____" __ Longitude

Direction and distance (km) from nearest town 1.2 km so. of Escondida Siding on W. side of Hwy 54, at BLM borrow area, ~15 mi so. Alamogordo N.M.

Stratigraphic unit, position, and thickness, or relationship with cultural materials (make sketch; use metric units) Dispersed caliche collected from upper 10 cm of calcic horizon of 2nd buried soil (from 3Ck horizon of that soil; see diagram at left).



Collected by Don Johnson Date collected March 17, 19 96

Name and address of person requesting analysis Don Johnson, 713 So Lynn St, Champaign, IL 61820

Title of project Tularosa Valley Project

Significance of sample Age of caliche will help determine age of 2nd buried soil, and will augment interpretation of when the 2nd soil became buried (and when 1st episode of land destabilization occurred here).

Your sample no. BLM-3

County Otero, N.M.

*numbers to be assigned by the ISGS

ISGS no.* 3348

Request no.* ______

Lab. no.* ______

References to relevant publications on geology of the area Monger, 1994.

Foreign matter or geologic factors that may contribute to anomalous age (e.g. root penetration, leaching, prolonged exposure to atmosphere, etc.) None

Sampling technique and post-sampling treatment Collected by hand from borrow pit wall.

Is more of this sample available if needed? yes

Expected age <5,000 RCYBP Possible age range from ______ to ______

Previously determined dates from same or adjacent horizons See BLM-1

remainder of form to be completed by ISGS

AUTHORIZATION FOR ANALYSIS

Date ______ 19__

______

Chairman, Radiocarbon Dating Committee

RESULTS OF ANALYSES

ISGS-______ Age = ______ ± ______ Radiocarbon Years B.P.

$\delta_{PDB}{}^{13}C$ = ______ per mil Activity = ______ ± ______ PMC

Remarks ______

Date ______ 19__ ______

Supervisor, Radiocarbon Dating Laboratory

NOTE: All age determinations will be submitted for publication in the journal Radiocarbon

Radiocarbon Date Comment Form
Illinois State Geological Survey
615 East Peabody Drive
Champaign, Illinois 61820
Telephone: (217) 244-2192

ISGS-3348

Age: **11710 ± 110 Radiocarbon Years BP** $\delta^{13}C$ = -3.9 per mil PDB

Sample: BLM-3

Site: BLM Caballo resource area

Material: Caliche

Location: 1.2km S of Escondida Siding

County: Otero State: NM Country: U.S.A.

Latitude: 00°00'00" N S Longitude: 00°00'00" E W

Stratigraphic Position:
From burial soil

Submitted by: Don Johnson

Submitters Institution: Univ of Illinois

Year collected: 1996 By: Don Johnson

Comment By (initials only): __ __ __
Comment: ______________________________

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Please check this form for accuracy, fill in any blanks, and return to the ISGS within two weeks (see reverse side for instructions).
April 21, 1996

ILLINOIS STATE GEOLOGICAL SURVEY

615 East Peabody Drive
Champaign, IL 61820
(217) 333-4747

G

REQUEST FOR RADIOCARBON AGE DETERMINATION

(Use separate sheet for each sample and TYPE or PRINT)

Date 6/20 1996

Name of section or site Snail Playa

Your sample number Snail Playa #1 Weight of sample (dry) ______ gms

Material to be analyzed Snail shell (Planorbis tenuis) - aquatic species

Material from which sample was taken same

Location: County Otero State N.M. Country USA

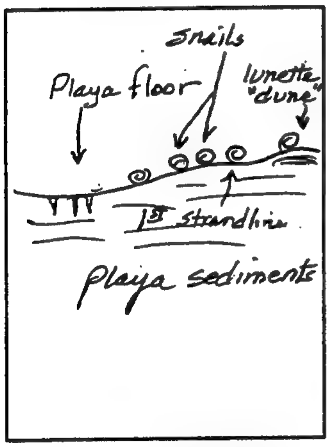
SW ¼ SE ¼ NW ¼ Section 6 Township 25S Range 8E

565-3389
7790±80

____° ____' ____" __ Latitude, ____° ____' ____" __ Longitude

Direction and distance (km) from nearest town ~4 Mi No. of McGregor Base Camp, McGregor Range, Ft Bliss, N.M.

Stratigraphic unit, position, and thickness, or relationship with cultural materials (make sketch; use metric units) Snails were lying off the deepest part of playa floor, on basined perimeter of playa, as well as on 1st strandline about 10' above playa floor. Some also collected from mini-lunette on NE side of 1st strandline.



Collected by Donald L. Johnson Date collected 6/12/96, 1996

Name and address of person requesting analysis Same

Title of project McGregor Range / Tularosa Valley Geologic Mapping Project.

Significance of sample If pre-bomb in age, the shells will almost certainly date from 1941-44 when playa had residual water for several years after the big rainfall year of 1941.

Your sample no. Snail Playa #1 ISGS no.* 3389

County Otero Request no.* 22375

numbers to be assigned by the ISGS Lab. no. D-2904

References to relevant publications on geology of the area Monger (1994)

Foreign matter or geologic factors that may contribute to anomalous age (e.g. root penetration, leaching, prolonged exposure to atmosphere, etc.) none

Sampling technique and post-sampling treatment All snails were sliced & dissected longitudinally with a razor blade, then washed thoroughly to remove all internal sediment, and oven dried.

Is more of this sample available if needed?

Expected age pre-bomb (1941-43) RCYBP Possible age range from 1985 to 1941

Previously determined dates from same or adjacent horizons None

remainder of form to be completed by ISGS

AUTHORIZATION FOR ANALYSIS

CLL for Leon R Follmer Date 7/8 1996

Chairman, Radiocarbon Dating Committee

RESULTS OF ANALYSES

ISGS-3389 Age = 790 ± 80 Radiocarbon Years B.P.

$\delta_{PDB}{}^{13}C$ = - 1.6 per mil Activity = ± PMC

Remarks

Date 7/8 1996 Chao-li Jack Liu

Supervisor, Radiocarbon Dating Laboratory

NOTE: All age determinations will be submitted for publication in the journal Radiocarbon

Radiocarbon Date Comment Form
Illinois State Geological Survey
615 East Peabody Drive
Champaign, Illinois 61820
Telephone: (217) 244-2192

ISGS-3389

Age: **790 ± 80 Radiocarbon Years BP** $\delta^{13}C$ = -1.6 per mil PDB

Sample: Snail playa #1

Site: Snail playa

Material: Snail shells

Location: 6.4km N of Mcgregor base camp

County: Otero State: NM Country: U.S.A.

Latitude: 00°00'00" N S Longitude: 00°00'00" E W

Stratigraphic Position:
From deepest part of playa floor

Submitted by: Donald L Johnson

Submitters Institution: Univ of Illinois

Year collected: 1996 By: D L Johnson

Comment By (initials only): __ __ __
Comment: ______________________________

Please check this form for accuracy, fill in any blanks, and return to the ISGS within two weeks (see reverse side for instructions).
July 6, 1996

NOTICE TO THE SUBMITTER

The information on the reverse side of this form is to be submitted for publication in the journal, RADIOCARBON. Please check to see that all information is correct and complete, and add your comment as to the significance of the date. Your comment should be brief but informative, and should point out why the sample was worth dating. A recent issue of RADIOCARBON may be used as a guide.

If the ISGS has completed a series of age determinations for you from the same locality, use another sheet to give a general comment summarizing the significance of the determinations as a whole. It may be necessary to edit your comment before publication, but any changes which could affect the meaning will be cleared with you.

As there are a great many man-hours that go into determining each date, your careful consideration of the result will be appreciated. If for some reason you would prefer to have this date published without a comment, write **"no comment"** on the form and sign it. **Completed forms should be returned within 2 weeks to:**

Chao-Li Jack Liu
Illinois State Geological Survey
615 East Peabody Drive
Champaign, IL 61820

If you have any questions concerning the date reported or the completion of this form, please feel free to call us.

NOTE: The date reported is a "conventional" radiocarbon date and refers to **Radiocarbon Years** before the reference year A.D. 1950. The date has been corrected for isotopic fractionation, but has not been corrected for the error in the half-life of ^{14}C, or for variations in the atmospheric concentration of ^{14}C. For this reason, the age in Radiocarbon Years may not be exactly equal to the age in solar years, or calendar years. Because use of the B.C.-A.D. time scale implies that the date is in terms of calendar years, **it is urged that the date not be converted to the B.C.-A.D. time scale** until after the above mentioned corrections have been applied.

Ages reported as greater than (>), are minimum ages only. For ages reported as MODERN, the numbers given refer only to the ^{14}C activity of the sample and should not be interpreted as indicating an age in years.

Date: Wed, 19 Jun 1996 22:22:06 -0500
X-Sender: shall@mail.utexas.edu
Mime-Version: 1.0
To: djohnson@ux1.cso.uiuc.edu (Donald Lee Johnson)
From: shall@mail.utexas.edu (Stephen A. Hall)
Subject: Roving Playas

Dear Don,

Well, I finished the first 4 pollen samples, making slides this morning. I haven't counted anything yet but will do so when I get back from new travels on July 1st (I'm giving 2 talks at the week-long International Palynological Congress in Houston and chairing the session on Quaternary Palynology). Also, the Gypsum Playa material is in acid but will have to wait completion until I get back to Austin.

I will report the result in order of good results, the best first.

1. Lake Tank Playa. I would have never guessed that this modest looking playa would have anything. But, the basal sample is loaded with lots of well preserved pollen. It is the best material I have seen from the El Paso area (except the 20th century coppice dune and woodrat middens). It is a good candidate for a research-level study. Of course age is everything. As it turns out, a 20-gram chunk of mud from the playa has more than enough organics for a good AMS date, on solid organic matter (equivalent to the pollen residue). Every pollen sample has enough organic matter for an AMS date; we could get a date for every decimeter of the playa.

2. Vertisol Playa. The basal sample contains lots of pollen, moderately preserved, with many charred particles but without the 'fluffy' organic debris of Lake Tank Playa. The pollen is suitable for scientific study, but I wonder about the integrity of the vertisol environment. One way to test its integrity is to AMS date several zones to see what the 14C age variation might be.

3. Escondido Playa. The base of this core has some pollen, poorly preserved, with lots of charred particles. The pollen has been partly altered by weathering. Again, there is enough charred particles for an AMS date. The pollen may or may not be suitable for scientific study--hard to say until I count this material.

4. Bassett Lake. A strong disappointment is the virtual lack of pollen from the lowest core material (8-foot depth). However, the sediments are characterized by secondary carbonates and some mottling---not surprising that it has little pollen. I observed a couple of pollen grains and I estimate, based on spike content, that the pollen will be <200 grains per gram----a very low amount. The pollen content is not suitable for study. However, there is a small amount of charred particles that could yield an AMS date. However, I would be skeptical of the 14C results since the organics in the core material have been largely lost via oxidation.

It appears that AMS dating of the playa sediments will pose no difficulty. I recommend first obtaining a reconn. 14C date from Lake Tank Playa, from the basal sediment. That will give us a ballpark value for chronology so we will know the time scale of the upper 2 meters and its pollen record.

We may be on to something bigger than we thought. The very different geology of each of the playas may be that we were looking at ones you chose in different settings. However, given the good potential to 14C date all the playa sequences, it may be possible to work out the sedimentation rates and depositional sequences of the different playas by region. This in turn could be related to local geomorphology and surficial processes at work in those different areas. Additionally, the pollen could give new information on vegetation/climatic history.

The pollen from Lake Tank and the Vertisol Playa, esp. Lake Tank, have tremendous paleoenvironmental potential----much more so than from any other locality I know about in the entire region (excluding woodrats). Although age control is vital, the organic matter content is sufficient to give us good AMS dates from any zone in the playa sequence. This is a first-time discovery. Others have reported pollen but did not know or could not judge its significance, and it was never pursued. I think this ought to be pursued.

Give it a thought. More later.

Steve

Stephen A. Hall
Department of Geography
University of Texas at Austin
Austin, Texas 78712-1098 U.S.A.

512-471-5116 work
512-471-5049 fax
shall@mail.utexas.edu
512-250-9111 home

DEPARTMENT OF GEOGRAPHY
THE UNIVERSITY OF TEXAS AT AUSTIN

Austin, Texas 78712-1098 · (512) 471-5116 · FAX (512) 471-5049

July 24, 1996

Beta Analytic Inc.
University Branch
4985 SW 74 Court
Miami, Florida 33155

Dear Colleagues:

Enclosed are two samples of organic matter that I have processed out of sediment, using palynologic techniques, that I want to radiocarbon dated via AMS.

McGregor - 1	Lake Tank Playa, 100-110 cm depth
McGregor - 2	Lake Tank Playa, 180-190 cm depth

Please send the results of the AMS analyses and the bill to:

Prof. Donald L. Johnson
Dept. of Geography
University of Illinois
Urbana, IL 61801

If any questions, please contact me.

Sincerely yours,

Stephen A. Hall

Stephen A. Hall
Associate Professor

BETA ANALYTIC INC.
DR. J.J. STIPP and DR. M.A. TAMERS

UNIVERSITY BRANCH
4985 S.W. 74 COURT
MIAMI, FLORIDA, USA 33155
PH: 305-667-5167 FAX: 305-663-0964

RADIOCARBON SAMPLE DATA SHEET

Please contact us at any time for advice, assistance or discussion of results.

SUBMITTER: Stephen A. Hall DATE July 24, 1996

AFFILIATION: Univ. of Texas at Austin

ADDRESS: Dept. of Geography TELEPHONE: 512-471-5116

Austin, Texas 78712 FAX: 512-471-5049

SUBMITTER'S SAMPLE CODE NO. McGregor - 1 PURCHASE ORDER NO.

INSTRUCTIONS TO LABORATORY
CHECK APPROPRIATE BOXES

DELIVERY ➧ NORMAL ☐ (30 day) PRIORITY ☐ (7 day) • TIME-GUIDE ☐ (48 HR) •

ANALYZE FOR ➧ RADIOCARBON ☒ $^{13}C/^{12}C$ ☐ $^{18}O/^{16}O$ ☐

SPECIAL HANDLING ➧ • (supplementary fees) EXTENDED COUNTING ☐ (enhanced precision) ACCELERATOR-AMS ☒ (very small sample) CELLULOSE ☐ (extraction)

COLLAGEN EXTRACTION ☐ (bone) BULK-LOW CARBON MATERIALS ☐ (soils, sediments)

OTHER:

SPECIAL INSTRUCTIONS (other than normal dating procedures) none

TYPE OF MATERIAL organic matter

WEIGHT ~0.1 g ESTIMATED AGE RANGE 2000 - 5000 yrs B.P.

EVIDENCE OF CONTAMINATION (ROOT PENETRATION, LEACHING, HUMUS, ETC)

none, possible secondary carbonates removed by HCl wash

COLLECTION, TREATMENT AND STORAGE PROCEDURES silty clay treated with HCl, HF, 2% NaOH, oven dried

STRATIGRAPHIC AND ENVIRONMENTAL DETAILS. (PUT DRAWINGS AND TEXT ON BACK)

Lake Tank Playa, 100 - 115 cm depth

BETA ANALYTIC INC.

DR. J.J. STIPP and DR. M.A. TAMERS

UNIVERSITY BRANCH
4985 S.W. 74 COURT
MIAMI, FLORIDA, USA 33155
PH: 305-667-5167 FAX: 305-663-0964

RADIOCARBON SAMPLE DATA SHEET

Please contact us at any time for advice, assistance or discussion of results.

SUBMITTER: Stephen A. Hall DATE July 24 1996

AFFILIATION: Univ. of Texas at Austin

ADDRESS: Dept. of Geography TELEPHONE: 512-471-5116

Austin, Texas 78712 FAX: 512-471-5049

SUBMITTER'S SAMPLE CODE NO. McGregor - 2 PURCHASE ORDER NO.

INSTRUCTIONS TO LABORATORY
CHECK APPROPRIATE BOXES

DELIVERY ➧ NORMAL ☐ (30 day) PRIORITY ☐ (7 day) * TIME-GUIDE ☐ (48 HR) *

ANALYZE FOR ➧ RADIOCARBON ☒ $^{13}C/^{12}C$ ☐ $^{18}O/^{16}O$ ☐

SPECIAL HANDLING ➧ * (supplementary fees)
EXTENDED COUNTING ☐ (enhanced precision)
ACCELERATOR-AMS ☒ (very small sample)
CELLULOSE ☐ (extraction)
COLLAGEN EXTRACTION ☐ (bone)
BULK-LOW CARBON MATERIALS ☐ (soils, sediments)

OTHER:

SPECIAL INSTRUCTIONS (other than normal dating procedures) none

TYPE OF MATERIAL organic matter

WEIGHT ~ ~~.02~~ 0.08g ESTIMATED AGE RANGE 2000 - 5000 yrs B.P.

EVIDENCE OF CONTAMINATION (ROOT PENETRATION, LEACHING, HUMUS, ETC)

none except possible secondary carbonates, removed by HCl wash

COLLECTION, TREATMENT AND STORAGE PROCEDURES silty clay treated with HCl, HF, 2% NaOH, oven dried

STRATIGRAPHIC AND ENVIRONMENTAL DETAILS. (PUT DRAWINGS AND TEXT ON BACK)

Lake Tank Playa 180 - 190 cm depth

DEPARTMENT OF GEOGRAPHY

THE UNIVERSITY OF TEXAS AT AUSTIN

Austin, Texas 78712-1098 · (512) 471-5116 · FAX (512) 471-5049

July 30, 1996

Dear Donald,

Enclosed is a FAX sent to me from Beta Analytic concerning the two AMS samples from Lake Tank Playa on the McGregor Range. According to their estimates, the 2 radiocarbon dates should be available to us by October 7, 1996. I consider this really good turn-around time.

I processed the two samples by washing about 100 grams of sediment in HCl, HF, and heavy liquid separation in zinc chloride (sg 2.0). The floatant was then washed in 2% NaOH, the same alkaline solution that radiocarbon samples are routinely washed in. Then the organic residue was oven dried (50^{0}C) until dry. The organic matter recovered from each 100-gram sample was about 0.8 and 0.5 grams (estimated). This is a lot of organics, magnitude more than needed for AMS dating. I'm really hopeful that we'll get good, useable dates.

The radiocarbon results along with the bill will be sent to you by Beta. I'm holding off on any more work on the samples until we get the ^{14}C results.

I hope all is going well for you and Diana in California or wherever you happen to be at present.

Best regards,

Steve

Stephen A. Hall

BETA ANALYTIC INC.

DR. MURRY TAMERS
MR. DARDEN HOOD
Co-directors

Tel: (01) 305-667-5167
FAX: (01) 305 663 0964
e-mail: beta@radiocarbon.com

To: Mr. Stephen A. Hall
University of Texas at Austin
FAX 1 512 471 5049

From: David Miller

We have received material for radiocarbon dating. Your correspondence is dated July 24, 1996. Results will be delivered on time.

IMPORTANT REMINDERS:

- We now offer a 20 business day delivery service.
- Delivery for bones and soils is now 30-45 business days.
- We are closed for the week of August 12 to 16. These days do not count as business days. Results needed prior to this week can still be obtained with the PRIORITY service.
- C13/C12 ratio analysis is recommended for bones, C4, CAMS plants, mixed species samples, and very young samples.

Comments/initial questions:

Please provide Dr. Johnson's phone ,fax and e-mail information (if applicable) so that we may update his file. The samples are cataloged under his name first (Johnson, D./ Hall, S.) since he will be receiving a copy of the results and the invoice. Will Dr. Johnson be paying via purchase order?

Service requested	Number of samples received	Expected Delivery by
Standard Radiometric (30 days)		Sept. 16, 1996
(soils & bones, 30-45 days)		Oct. 7, 1996
ADVANCE Radiometric (20 days)		Aug. 30, 1996
(soils & bones, 20-30 days)		Sept. 16, 1996
PRIORITY Radiometric (6 days)		Aug. 6, 1996
(soils & bones, 6-14 days)		Aug. 23, 1996
Standard AMS (30-45 days)	2	Oct. 7, 1996
ADVANCE AMS (6-14 days)		Aug. 23, 1996

Date: Tue, 6 Aug 1996 18:24:27 -0500
X-Sender: shall@mail.utexas.edu
Mime-Version: 1.0
To: djohnson@ux1.cso.uiuc.edu (Donald Lee Johnson)
From: shall@mail.utexas.edu (Stephen A. Hall)
Subject: FAX, hello

Dear Don,

Yes, I'm excited about the AMS dates and the prospects of getting the first firm radiocarbon dates on playa sediments from virtually anywhere in the Southwest---the icing on the cake is that Lake Tank Playa (LTP) has pollen! I anticipate that the age of the upper 2 meters of LTP sediments is Holocene, even late Holocene. Regardless the age, the potential pollen record from LTP will be the first good pollen data from the northern Chihahuan Desert and will be an important step at vegetational and paleoclimatic reconstruction in the region. I don't have to exaggerate the significance of this potential record.

Of course a firmly-established paleoclimatic record is vital to any correlation of geomorphic/soil processes through time with climate change.

Also, it seems that the different geologic origin/filling of the various playas on the McGregor Range would be an interesting story to see unfolded. Your work there this summer lays the groundwork for such a project.

Overall there seems to be a lot of new work that can be done there.

Best regards to you and Diana.

Steve

Stephen A. Hall
Department of Geography
University of Texas at Austin
Austin, Texas 78712 U.S.A.

512-471-5116 work

BETA ANALYTIC INC.
DR. M.A. TAMERS and MR. D.G. HOOD

UNIVERSITY BRANCH
4985 S.W. 74 COURT
MIAMI, FLORIDA, USA 33155
PH: 305/667-5167 FAX: 305/663-0964
E-MAIL: beta@radiocarbon.com

REPORT OF RADIOCARBON DATING ANALYSES

:OR: Dr. Donald L. Johnson
University of Illinois

DATE RECEIVED: July 29, 1996
DATE REPORTED: October 2, 1996

Sample Data	Measured C14 Age	C13/C12 Ratio	Conventional C14 Age (*)
ɘta-95521	2650 +/- 60 BP	-20.3 o/oo	2730 +/- 60 BP

ᗅMPLE #: McGregor-1
ᑎALYSIS: AMS (LLNL)
ᗅTERIAL/PRETREATMENT:(organic material): none

ɘta-95522	5270 +/- 60 BP	-24.4 o/oo	5280 +/- 60 BP

ᗅMPLE #: McGregor-2
ᒍALYSIS: AMS (LLNL)
ᗅTERIAL/PRETREATMENT:(organic material): none

)TE: It is important to read the calendar calibration information
ıd to use the calendar calibrated results (reported separately) when
ıterpreting these results in AD/BC terms.

Dates are reported as RCYBP (radiocarbon years before present, "present" = 1950A.D.). By International convention, the modern reference standard was 95% of the C14 content of the National Bureau of Standards' Oxalic Acid & calculated using the Libby C14 half life (5568 years). Quoted errors represent 1 standard deviation statistics (68% probability) & are based on combined measurements of the sample, background, and modern reference standards.

Measured C13/C12 ratios were calculated relative to the PDB-1 international standard and the RCYBP ages were normalized to -25 per mil. If the ratio and age are accompanied by an (*), then the C13/C12 value was estimated, based on values typical of the material type. The quoted results are NOT calibrated to calendar years. Calibration to calendar years should be calculated using the Conventional C14 age.

CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables:C13/C12=-20.3:lab mult.=1)

Laboratory Number: Beta-95521

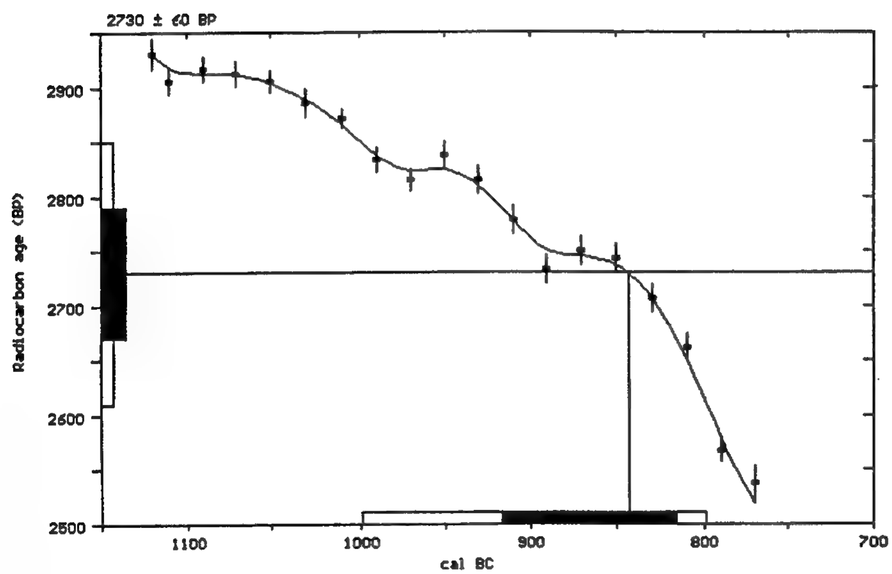
Conventional radiocarbon age: **2730 ± 60 BP**

Calibrated results: (2 sigma, 95% probability) **cal BC 1000 to 800**

Intercept data:

Intercept of radiocarbon age with calibration curve: cal BC 845

1 sigma calibrated results: (68% probability) cal BC 915 to 815



References:

Pretoria Calibration Curve for Short Lived Samples
Vogel, J. C., Fuls, A., Visser, E. and Becker, B., 1993, Radiocarbon 35(1), p73-86
A Simplified Approach to Calibrating C14 Dates
Talma, A. S. and Vogel, J. C., 1993, Radiocarbon 35(2), p317-322
Calibration - 1993
Stuiver, M., Long, A., Kra, R. S. and Devine, J. M., 1993, Radiocarbon 35(1)

Beta Analytic Radiocarbon Dating Laboratory

4985 S.W. 74th Court, Miami, Florida 33155 ■ Tel: (305)667-5167 ■ Fax: (305)663-0964 ■ E-mail: beta@radiocarbon.com

CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-24.4:lab. mult=1)

Laboratory Number: Beta-95522

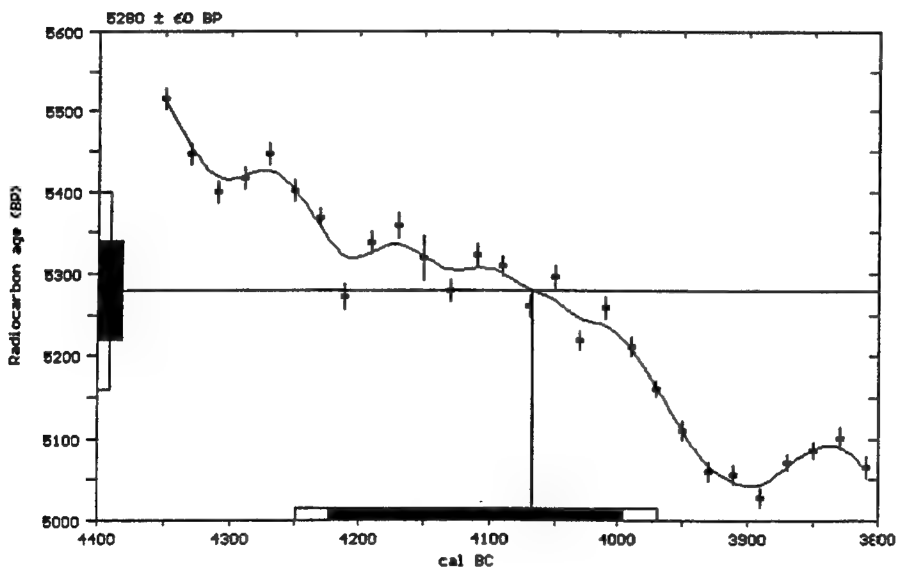
Conventional radiocarbon age: **5280 ± 60 BP**

Calibrated results: **cal BC 4250 to 3970**
(2 sigma, 95% probability)

Intercept data:

Intercept of radiocarbon age with calibration curve: cal BC 4070

1 sigma calibrated results: cal BC 4220 to 3995
(68% probability)



References:

Pretoria Calibration Curve for Short Lived Samples
Vogel, J. C., Fuls, A., Visser, E. and Becker, B., 1993, Radiocarbon 35(1), p73-86
A Simplified Approach to Calibrating C14 Dates
Talma, A. S. and Vogel, J. C., 1993, Radiocarbon 35(2), p317-322
Calibration - 1993
Stuiver, M., Long, A., Kra, R. S. and Devine, J. M., 1993, Radiocarbon 35(1)

Beta Analytic Radiocarbon Dating Laboratory

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EXPLORATORY POLLEN EXTRACTION OF THREE SAMPLES FROM BASSETT LAKE, HUECO MOUNTAINS, MEXICO

By

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INTRODUCTION

Three stratigraphic pollen samples were selected for extraction and scanning to observe whether or not pollen was present and if it was in a sufficiently good state of preservation for identification.

METHODS

A chemical extraction technique based on flotation is the standard preparation technique used in this laboratory for the removal of the pollen from the large volume of sand, silt, and clay with which they are mixed. This particular process was developed for extraction of pollen from soils where preservation has been less than ideal and pollen density is low. Sample size ranged from 10 ml. to 25 ml. for the sediments examined. All of the sample submitted was extracted.

Hydrochloric acid (10%) was used to remove calcium carbonates present in the soil, after which the samples were screened through 150 micron mesh. The samples were rinsed until neutral by adding water, letting the samples stand for 2 hours, then pouring off the supernatant. A small quantity of sodium hexametaphosphate was added to each sample once it reached neutrality, then the beaker was again filled with water and allowed to stand for 2 hours. The samples were again rinsed until neutral, filling the beakers only with water. This step was added to remove clay prior to heavy liquid separation. At this time the samples are dried then pulverized. Zinc bromide (density 2.1) was used for the flotation process. The samples were mixed with zinc bromide and centrifuged at 1500 rpm for 10 minutes to separate organic from inorganic remains. The supernatant containing pollen and organic remains is decanted and diluted. Zinc bromide is again added to the inorganic fraction to repeat the separation process. After rinsing the pollen-rich organic fraction obtained by this separation, all samples received a short (20 minute) treatment in hot hydrofluoric acid to remove any remaining inorganic particles. The samples were then acetolated for 3 minutes to remove any extraneous organic matter.

A light microscope was used to scan the pollen samples at a magnification of 400x. Pollen preservation in these samples varied from excellent to poor.

DISCUSSION AND RECOMMENDATIONS

Visual examination of the three samples (Table 1) submitted for preliminary scans indicates that pollen is present at depths ranging from 10 cm to 112 cm at Bassett Lake. The upper two samples (10-12 cm and 50-52 cm) yielded an abundance of pollen. Sample sizes were 25 ml for the uppermost sample and 15 ml for the sample collected from 50-52 cm. The smallest sample (10 ml), collected at a depth of 110-112 cm, yielded sufficient pollen to obtain a statistically valid count. All samples exhibited a variety of pollen types sufficient to suggest that an interpretable pollen record exists in these sediments.

TABLE 1
PROVENIENCE DATA FOR SAMPLES FROM BASSETT LAKE

Depth (cm)	Provenience/Description	Pollen evaluation
10-12	Fill from Bassett Lake	Excellent
50-52	Fill from Bassett Lake	Good to Excellent
110-112	Fill from Bassett Lake	Preservation not as good, but pollen quantity and variety adequate for analysis

A decline in total pollen per ml of sediment was noted with increasing depth, as is expected. Therefore, small samples, such as 10 ml to 15 ml, are not recommended for future analysis from this playa. Extrapolating from the quantity of pollen recovered from the 110-112 cm depth, a sample of at least 25 ml is recommended near that depth. If the stratigraphic column is sampled at depths greater than this, larger samples, up to approximately 50 ml, are recommended. It should be noted that when working with sediments, a 50 ml sample is considered standard. Samples smaller than 50 ml are considered to be small.

Evaluation of the suitability of Bassett Lake for future paleoenvironmental studies should include an examination of suitability for radiocarbon dating, since any pollen analysis will rely heavily upon dated intervals for interpretation. Certainly the pollen preservation and abundance in these samples indicates that an interpretable record exists at Bassett Lake in the upper 112 cm.

APPENDIX B

CLIMATOLOGICAL DATA:
MONTHLY AND ANNUAL PRECIPITATION DATA
FOR SOUTHCENTRAL NEW MEXICO AND WEST TEXAS

ALAMOGORDO, NM (Station: 290199; Elev. 4,350 ft)
From Year 1914 to 1995

Year	Total Precipitation (in)												
	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1914	0.00	0.22	0.55	0.38	1.50	3.45	4.05	2.03	0.50	1.49	0.81	2.81	17.79
1915	0.53	0.90	1.89	2.22	0.02	0.00	1.60	0.79	3.08	0.00	0.00	0.87	11.90
1916	0.59	0.13	1.11	0.35	1.08	0.00	0.47	1.61	0.95	2.37	0.00	0.35	9.01
1917	0.53	0.00	0.00	0.00	0.60	0.60	0.20	3.49	0.10	0.00	0.00	0.00	5.52
1918	0.82	0.25	0.22	0.00	0.00	0.91	0.58	1.20	0.08	2.97	1.60	0.00	8.63
1919	0.02	0.09	2.32	1.87	0.27	1.76	2.81	1.14	3.30	0.69	0.90	0.44	15.61
1920	1.19	1.23	0.24	0.00	0.51	1.89	1.62	2.42	0.61	0.83	0.00	0.00	10.54
1921	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1922	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1923	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1924	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1925	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1926	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1927	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1928	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1929	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1930	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1931	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1932	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1933	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1934	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1935	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1936	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1937	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1938	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1939	0.82	0.00	0.55	0.24	0.16	0.09	1.07	1.91	2.54	1.35	0.43	0.67	9.83
1940	0.38	0.78	0.00	0.10	1.60	1.25	1.20	0.22	0.27	0.45	0.94	0.30	7.49
1941	1.13	1.18	1.34	1.29	3.03	0.36	1.26	1.96	6.94	2.63	0.14	0.61	21.87
1942	0.16	0.36	0.00	2.13	0.00	0.97	0.43	3.42	1.48	nd	0.00	2.33	$\geq$11.28
1943	0.18	0.00	0.00	0.00	0.23	2.56	0.54	0.88	0.36	0.08	1.12	1.93	7.88

ALAMOGORDO, NM (Station: 290199; Elev. 4,350 ft) From Year 1914 to 1995 (cont'd)

Year	Total Precipitation (in)												
	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1944	1.13	0.82	0.32	0.06	0.40	1.08	1.24	2.37	0.99	0.10	0.99	0.52	10.02
1945	0.62	0.00	0.08	0.00	0.00	0.05	2.96	1.96	0.15	1.48	0.00	0.35	7.65
1946	1.33	0.00	0.10	0.04	0.50	0.38	2.52	1.25	1.55	0.33	1.56	0.28	9.84
1947	1.35	0.20	0.47	0.00	0.11	0.19	1.63	1.56	0.26	0.35	0.84	0.58	7.54
1948	1.07	0.94	0.12	nd	1.88	1.02	0.89	2.10	0.09	1.07	0.15	0.95	≥10.28
1949	2.61	0.78	0.00	1.31	0.10	0.99	1.52	1.02	2.52	1.63	nd	0.66	≥13.14
1950	0.00	0.10	0.00	0.00	0.00	0.64	3.87	0.36	2.42	1.05	0.00	0.00	8.44
1951	1.09	0.10	0.69	0.66	0.05	0.00	0.56	1.74	0.00	0.60	0.22	0.22	5.93
1952	0.30	0.28	0.65	0.61	0.11	0.88	0.61	0.17	0.17	0.00	0.27	0.80	4.85
1953	0.00	0.89	0.36	nd	0.17	2.44	2.81	1.33	0.56	0.93	0.03	0.12	≥9.64
1954	0.09	0.04	0.10	0.04	0.53	0.30	2.18	1.83	1.23	0.09	0.00	0.00	6.43
1955	1.40	0.00	0.57	0.00	0.06	0.19	5.40	0.20	1.56	1.08	0.00	0.00	10.46
1956	0.00	0.45	0.00	nd	0.00	0.43	0.86	0.08	0.23	0.69	0.00	0.19	≥2.93
1957	0.44	1.22	0.64	0.37	nd	0.00	0.96	3.52	0.93	3.25	0.84	0.00	≥12.17
1958	0.89	0.45	3.02	0.58	0.44	1.07	1.12	2.70	3.09	1.50	0.39	0.00	15.25
1959	0.00	0.54	0.00	0.10	0.66	0.41	1.35	6.67	0.02	0.45	0.04	0.54	10.78
1960	1.41	0.30	0.14	0.00	0.66	0.98	2.27	0.55	0.74	0.79	0.09	1.54	9.47
1961	0.53	0.03	0.61	0.00	0.03	1.34	1.16	3.18	1.80	0.09	1.24	1.29	11.30
1962	1.29	0.49	0.19	0.21	0.00	0.29	4.53	0.79	2.85	1.04	0.44	0.84	12.96
1963	0.34	0.35	0.00	nd	0.02	0.01	1.38	2.54	2.03	1.34	0.15	0.03	≥8.19
1964	0.15	0.43	0.42	0.17	0.11	0.00	0.99	1.32	2.85	0.02	0.00	0.28	6.74
1965	0.59	0.56	1.01	0.20	0.04	0.88	2.22	3.03	2.14	0.51	0.08	1.76	13.02
1966	0.96	0.48	0.02	0.33	0.28	2.19	2.55	1.51	1.18	0.01	0.15	0.10	9.76
1967	0.00	0.51	0.10	0.02	0.18	2.21	2.39	1.68	1.35	0.02	0.92	1.47	10.85
1968	0.89	0.99	1.73	0.04	0.22	0.09	3.26	2.90	0.01	0.19	1.20	0.43	11.95
1969	0.44	0.74	0.34	0.04	1.37	0.12	2.59	3.00	2.04	2.19	0.10	1.21	14.18
1970	0.09	0.40	0.74	0.03	0.56	0.53	1.09	1.00	0.23	0.87	0.00	0.34	5.88
1971	0.05	0.28	0.00	0.86	0.15	0.64	3.01	1.89	1.26	2.22	1.28	0.76	12.40
1972	0.80	0.07	0.00	0.00	0.00	1.32	1.69	5.73	2.50	nd	0.42	0.83	≥13.36
1973	0.95	0.79	2.16	0.00	0.65	1.29	4.29	0.56	0.14	0.14	0.03	0.00	11.00
1974	0.94	0.14	0.22	0.05	0.00	0.85	4.22	1.22	2.39	5.66	0.28	0.76	16.73
1975	0.69	0.80	0.74	0.02	0.02	0.53	0.96	0.97	6.24	0.00	0.33	0.00	11.30

ALAMOGORDO, NM (Station: 290199; Elev. 4,350 ft) From Year 1914 to 1995

Year	Total Precipitation (in)												
	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1976	0.12	0.16	0.04	0.55	2.36	0.47	6.36	0.52	3.64	1.25	0.81	0.00	16.28
1977	0.84	0.29	0.40	1.15	0.53	0.31	0.93	2.58	1.00	1.65	0.43	0.33	10.44
1978	1.30	1.15	0.33	0.07	1.19	1.38	1.07	nd	1.80	2.19	2.91	nd	≥13.39
1979	1.19	0.77	0.00	nd	nd	1.99	2.25	3.93	1.63	0.02	0.00	0.96	≥12.74
1980	0.88	0.79	0.15	0.07	0.56	0.15	0.29	3.74	3.29	0.14	0.10	0.09	10.25
1981	0.79	0.66	0.60	0.00	0.09	0.68	2.23	3.53	2.20	0.81	0.64	0.33	12.56
1982	1.20	0.29	0.00	0.00	0.66	0.41	1.25	2.26	4.01	0.00	0.33	2.36	12.77
1983	1.40	0.78	0.28	0.74	0.29	1.30	1.52	0.29	1.00	1.68	2.37	0.68	12.33
1984	0.15	0.00	0.05	0.18	0.73	1.87	1.62	4.13	0.22	3.27	2.12	3.01	17.35
1985	0.98	0.23	1.11	0.90	0.04	0.89	2.15	2.03	3.66	6.09	0.14	0.12	18.34
1986	0.00	0.72	0.68	0.00	0.68	1.70	2.44	2.28	1.63	1.15	3.40	1.91	16.59
1987	0.50	0.54	0.24	0.73	0.68	2.16	0.96	2.76	0.95	0.58	0.64	1.10	11.84
1988	0.62	1.18	0.20	0.31	0.06	1.38	1.62	4.44	0.68	0.43	0.01	0.73	11.66
1989	0.61	1.03	0.45	0.00	0.21	0.01	3.17	3.46	1.35	0.10	0.08	0.62	11.09
1990	1.07	0.52	1.12	0.94	0.53	0.15	2.78	2.35	3.53	0.76	0.63	0.73	15.11
1991	1.02	1.12	0.20	0.00	0.43	0.20	1.18	4.50	3.17	0.34	0.97	5.45	18.58
1992	1.98	0.21	1.13	0.88	3.56	0.44	2.15	1.17	0.51	0.70	0.10	1.61	14.44
1993	1.97	0.57	0.00	0.33	0.56	0.73	3.56	2.70	0.12	0.86	0.97	0.39	12.76
1994	0.50	0.17	0.87	0.44	1.85	0.25	2.45	0.93	1.13	0.90	1.22	1.43	12.14
1995	0.76	0.46	0.10	0.00	0.06	0.65	1.65	2.22	2.51	0.00	0.16	0.66	9.23
Average	0.72	0.48	0.49	0.36	0.53	0.84	1.97	2.08	1.62	1.05	0.57	0.78	11.56

nd = missing

ALAMOGORDO 1, NM (Station: 290200)
From 1901 to 1943

Year	Total Precipitation (in) January	February	March	April	May	June	July	August	September	October	November	December	Annual
1901	0.15	1.35	0.19	0.41	0.22	0.38	1.47	1.59	1.18	2.59	2.13	0.10	11.74
1902	0.00	0.16	0.22	0.00	0.00	0.17	1.38	3.38	0.53	0.65	0.15	0.60	7.24
1903	0.30	1.00	0.40	0.00	0.48	1.30	0.83	1.48	1.16	0.00	0.00	nd	6.95
1904	0.50	0.10	0.00	0.00	0.00	0.13	0.81	2.01	2.10	2.38	0.17	0.75	8.95
1905	1.02	2.45	1.85	3.34	0.00	1.84	2.88	0.41	1.78	0.34	2.75	0.86	19.52
1906	0.85	0.74	0.26	0.99	0.27	0.00	0.72	1.91	0.42	0.43	2.24	2.35	11.18
1907	1.45	0.07	0.00	0.35	0.23	0.78	0.93	3.74	1.74	0.84	0.75	0.00	10.88
1908	1.15	0.30	0.42	1.29	0.08	0.13	4.30	3.06	0.26	0.19	0.83	0.00	12.01
1909	0.95	0.00	1.00	0.00	0.00	0.17	0.62	1.88	1.14	0.13	0.00	0.94	6.83
1910	0.40	0.00	0.20	0.12	0.04	1.00	0.99	4.05	0.00	0.70	1.10	0.05	8.65
1911	0.21	1.96	0.62	0.84	0.94	0.54	2.75	0.59	2.31	1.46	0.18	0.29	12.69
1912	0.04	0.61	0.47	0.55	0.14	1.05	0.22	4.11	1.00	1.56	0.00	0.45	10.20
1913	0.57	1.77	0.05	0.89	0.05	1.66	0.01	1.87	2.05	0.00	1.90	1.56	12.38
1914	0.06	0.26	0.72	0.36	2.11	2.56	4.18	2.05	0.60	1.79	1.13	2.61	18.43
1915	0.50	0.66	1.67	2.02	0.03	0.00	1.92	0.71	5.45	0.04	0.00	0.91	13.91
1916	1.35	0.09	0.91	0.20	1.06	0.00	1.38	2.44	1.21	3.35	0.00	0.47	12.46
1917	0.34	0.04	0.01	0.00	0.63	0.10	0.55	3.06	0.36	0.00	0.11	0.00	5.20
1918	1.27	0.19	0.23	0.00	0.00	0.78	1.37	1.22	0.14	3.60	1.46	1.21	11.47
1919	0.00	0.00	2.28	1.67	0.23	1.43	2.47	1.17	3.16	0.69	1.59	0.25	14.94
1920	0.78	0.30	0.48	0.00	0.53	2.75	1.63	2.57	0.41	1.01	0.00	0.00	10.46
1921	nd	nd	0.12	0.00	0.44	0.91	2.57	2.62	1.71	0.00	0.20	nd	8.57
1922	0.87	0.02	0.07	0.73	0.00	0.96	0.38	0.87	0.95	1.75	0.68	0.19	7.47
1923	1.18	1.30	0.39	0.71	0.00	0.09	2.87	3.77	0.53	0.49	2.79	0.92	15.04
1924	0.28	0.03	0.83	0.50	0.00	0.01	2.25	2.10	0.00	0.32	0.25	0.52	7.09
1925	nd	nd	0.00	0.00	1.29	0.47	1.36	0.51	0.53	2.24	0.15	0.75	$\geq$7.30
1926	0.77	0.16	nd	0.58	2.24	0.10	2.88	0.38	3.75	2.41	0.00	1.94	$\geq$15.21
1927	0.01	0.32	0.93	0.00	0.00	0.95	1.56	2.38	1.33	0.05	0.00	0.18	7.71
1928	0.00	1.07	0.00	0.10	2.08	0.01	0.93	2.78	0.64	3.05	1.39	0.22	12.27
1929	0.04	0.30	0.22	0.00	1.08	0.00	2.06	3.26	0.74	1.09	0.90	0.28	9.97

ALAMOGORDO 1, NM (Station: 290200) From Year 1901 to 1943 (cont'd)

Year	Total Precipitation (in)												
	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1930	0.40	0.05	0.06	0.14	0.47	0.22	2.91	2.13	0.28	1.21	1.28	0.55	9.70
1931	1.28	1.72	0.03	1.81	0.90	0.66	1.93	3.30	3.44	0.75	1.38	0.53	17.73
1932	1.29	0.89	0.58	0.15	0.39	0.69	2.13	3.26	1.64	1.68	0.00	1.08	13.78
1933	0.25	0.31	0.45	0.10	0.33	2.10	2.77	1.26	0.63	0.25	nd	0.04	≥8.49
1934	0.00	0.12	0.89	0.05	0.61	0.13	0.93	1.61	0.39	0.60	nd	0.27	≥5.60
1935	0.68	0.38	0.04	0.11	0.91	1.04	1.07	3.27	3.43	0.03	1.49	0.67	13.12
1936	1.56	0.02	0.00	0.17	1.45	0.79	1.94	0.98	3.62	0.56	0.93	0.28	12.30
1937	0.00	0.95	nd	0.00	1.34	0.47	0.28	0.63	1.58	nd	0.00	0.74	≥5.99
1938	0.86	1.01	0.12	0.18	0.20	1.84	2.40	1.48	5.61	0.19	0.47	0.90	15.26
1939	1.38	0.00	0.77	0.20	0.00	0.30	1.81	2.77	2.49	1.99	0.86	0.50	13.07
1940	0.53	1.01	0.10	0.01	2.09	1.13	0.95	0.39	0.31	0.55	1.15	0.33	8.55
1941	1.35	1.66	2.10	1.29	2.75	0.81	1.22	2.52	10.78	3.57	0.26	1.06	29.37
1942	0.26	0.49	0.10	2.57	0.03	0.98	1.88	3.47	2.30	1.60	0.00	1.84	15.52
1943	0.10	nd	0.63	nd	nd	0.00	nd	nd	0.65	nd	nd	nd	nd
Average	0.60	0.58	0.49	0.53	0.62	0.73	1.67	2.12	1.72	1.12	0.76	0.67	12.42

nd = missing

CLOUDCROFT, NM (Station: 291927; Elev. 8,650 ft)
From Year 1902 to 1987

Year	Total Precipitation (in)												
	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1902	1.23	0.50	1.45	0.00	0.00	nd	nd	nd	2.26	0.14	1.31	2.00	nd
1903	0.99	4.60	0.90	0.15	1.20	4.01	0.66	2.98	1.85	0.50	0.00	0.28	18.12
1904	0.85	0.10	0.00	nd	nd	1.63	4.23	3.69	6.16	4.37	0.55	1.36	nd
1905	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1906	1.00	1.72	1.47	1.60	1.17	0.00	3.35	3.36	5.44	1.29	3.55	4.73	28.68
1907	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1908	1.96	2.00	1.00	0.53	0.07	0.00	2.68	7.61	0.39	0.35	0.80	0.10	17.49
1909	1.10	2.40	2.10	0.00	0.00	1.30	nd	nd	2.77	0.52	0.20	nd	nd
1910	0.90	nd	0.30	nd	0.10	1.84	2.71	7.31	nd	0.68	0.15	0.75	nd
1911	0.20	3.11	0.85	0.40	0.00	1.22	6.06	1.06	3.99	1.80	0.33	1.39	20.41
1912	0.06	1.42	0.42	0.59	0.30	3.10	4.17	6.95	2.97	nd	0.59	0.78	nd
1913	1.13	2.61	1.15	0.91	0.00	0.75	nd	2.15	3.83	0.00	1.42	3.23	nd
1914	0.55	0.72	1.15	0.38	0.64	0.60	8.02	3.56	0.89	1.46	0.65	3.13	21.75
1915	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1916	4.41	0.35	1.82	0.87	1.32	0.00	3.35	6.90	3.70	3.22	0.56	0.92	27.42
1917	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1918	3.51	1.08	1.25	0.00	0.00	2.56	4.57	7.47	0.39	2.64	3.05	2.00	28.52
1919	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1920	1.37	1.15	1.39	1.34	nd	5.85	3.61	4.40	2.31	1.97	0.00	0.28	nd
1921	0.21	0.87	0.87	0.00	0.95	1.70	5.65	3.91	3.76	0.00	0.21	0.63	18.76
1922	2.07	0.15	0.57	0.87	0.00	1.99	1.89	4.15	1.16	1.97	1.47	0.31	16.60
1923	1.15	2.52	1.51	0.75	1.20	0.41	5.90	7.21	1.33	0.00	3.51	3.58	29.07
1924	0.81	0.51	1.50	0.72	0.50	nd	6.61	2.74	0.34	0.90	0.35	1.73	nd
1925	0.91	0.95	0.00	0.00	1.66	1.22	7.34	5.32	3.37	2.81	0.28	0.43	24.29
1926	2.80	0.40	4.74	0.43	nd	1.26	3.96	3.83	4.27	4.40	nd	3.19	nd
1927	0.10	1.11	3.19	0.36	0.00	1.51	9.52	8.69	4.18	0.00	0.00	1.13	29.79
1928	0.06	2.23	0.13	0.37	3.53	0.00	4.87	8.44	1.09	3.58	1.40	0.29	25.99
1929	0.84	1.70	0.58	0.00	2.74	0.21	6.16	5.87	1.78	2.20	1.51	0.62	24.21
1930	1.62	0.44	1.05	0.58	3.98	0.97	4.95	5.03	1.68	1.64	2.86	1.01	25.81
1931	1.14	4.75	1.34	3.18	1.52	0.56	6.64	nd	4.65	1.16	3.95	3.74	nd
1932	3.07	2.28	4.01	0.51	1.34	2.25	5.79	6.80	3.72	3.21	0.00	2.56	35.54

CLOUDCROFT, NM (Station: 291927) (Elev. 8,650 ft) From Year 1902 to 1987

Year	Total Precipitation (in)												
	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1933	3.04	2.69	0.48	0.52	2.15	3.61	3.56	3.33	1.10	1.32	0.89	0.05	22.74
1934	0.40	0.40	0.83	0.49	1.85	0.25	4.01	3.08	0.60	1.00	1.96	2.28	17.15
1935	1.61	2.48	1.31	0.29	1.50	1.31	1.88	6.12	2.20	0.00	1.45	0.53	20.68
1936	4.02	2.11	0.60	0.53	2.56	1.52	4.69	3.51	4.75	0.75	0.81	1.64	27.49
1937	0.55	2.46	3.35	0.35	2.16	4.55	2.46	3.42	3.40	2.14	0.20	2.12	27.16
1938	1.69	2.80	0.80	0.64	0.53	2.81	8.06	2.34	3.80	0.30	1.11	1.11	25.99
1939	1.88	2.26	1.16	0.58	0.55	0.72	5.44	4.34	2.82	2.15	1.52	1.14	24.56
1940	1.22	2.55	0.42	0.33	2.52	1.71	5.90	2.68	2.28	2.07	1.32	1.51	24.51
1941	2.83	2.48	2.90	2.20	5.20	1.87	8.97	4.38	11.62	3.85	0.87	0.93	48.10
1942	0.69	1.85	1.12	3.49	0.00	0.62	4.37	8.84	4.39	3.06	0.00	3.46	31.89
1943	0.83	0.09	1.01	0.00	0.81	6.17	8.04	3.08	1.57	0.09	0.82	2.34	24.85
1944	2.98	1.61	0.60	1.10	0.48	1.18	7.41	4.12	2.52	0.74	1.86	0.94	25.54
1945	1.49	0.24	1.17	0.16	0.00	0.30	4.66	7.18	0.60	1.31	0.00	1.38	18.49
1946	5.24	0.62	2.74	0.73	1.45	1.52	6.52	2.40	2.72	nd	0.98	1.23	nd
1947	1.26	0.63	0.72	0.42	1.21	0.57	2.45	5.05	1.06	nd	nd	nd	nd
1948	nd	nd	nd	nd	1.40	1.56	4.00	2.97	0.85	2.47	0.14	3.33	nd
1949	3.69	1.57	0.53	1.46	0.22	4.16	7.12	6.30	3.27	1.59	0.13	1.83	31.87
1950	0.55	0.46	0.10	0.28	0.01	3.08	10.75	1.19	3.47	1.11	0.00	0.00	21.00
1951	1.42	0.92	2.56	1.09	0.18	0.15	7.73	3.43	0.35	2.53	1.11	1.84	23.31
1952	0.39	0.99	1.83	1.81	0.53	4.30	5.62	5.91	1.30	nd	nd	nd	nd
1953	nd	nd	1.53	2.23	0.05	2.54	3.77	2.58	0.02	0.95	0.59	2.15	nd
1954	1.35	0.24	1.73	0.00	0.99	2.01	3.89	6.18	1.98	1.11	0.00	0.35	19.83
1955	2.37	0.55	3.82	0.00	0.81	0.44	10.48	5.29	0.55	2.06	0.16	0.22	26.75
1956	1.16	2.25	0.00	0.57	0.00	1.42	5.13	3.84	0.02	1.55	0.00	0.90	16.84
1957	1.50	2.74	3.51	1.01	0.56	0.40	3.02	7.02	0.41	4.72	2.40	0.34	27.63
1958	3.16	3.28	7.31	1.06	0.65	1.25	4.66	7.51	4.78	3.06	0.85	0.23	37.80
1959	0.04	1.31	0.10	0.05	0.32	1.53	8.84	6.90	0.05	0.64	0.06	1.22	21.06
1960	4.21	1.77	0.43	0.14	1.04	1.47	6.98	2.23	0.92	1.59	0.11	2.21	23.10
1961	1.69	0.10	2.75	0.03	0.50	4.23	6.44	4.10	2.77	0.25	2.68	5.10	30.64
1962	3.13	0.91	1.36	0.50	0.22	1.72	9.61	2.19	4.41	1.50	1.54	1.38	28.47
1963	2.57	1.37	0.04	0.59	0.24	0.78	5.49	9.23	1.96	1.59	0.68	0.40	24.94
1964	0.51	1.60	1.56	0.71	0.95	0.78	6.39	3.16	4.65	0.00	0.19	0.93	21.43

CLOUDCROFT, NM (Station: 291927) (Elev. 8,650 ft) From 1902 to 1987 (cont'd)

Year	Total Precipitation (in)												
	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1965	1.74	2.90	2.14	0.82	0.51	2.56	5.70	6.88	3.39	1.08	0.53	5.73	33.98
1966	1.59	1.72	1.22	0.96	0.00	3.15	3.81	6.27	3.15	0.00	1.15	1.59	24.61
1967	0.00	1.55	0.28	0.08	0.02	2.65	2.64	7.95	4.67	0.02	1.01	5.26	26.13
1968	1.59	2.07	3.85	0.11	0.28	0.64	5.21	6.05	0.76	0.62	3.14	2.87	27.19
1969	1.44	1.66	1.56	0.00	2.56	0.29	4.21	7.13	5.22	1.40	nd	nd	nd
1970	0.40	0.13	1.84	0.10	0.04	2.51	4.44	nd	nd	1.03	0.05	0.46	nd
1971	nd	2.00	0.00	1.54	0.27	2.94	4.23	nd	2.26	4.44	0.16	2.12	nd
1972	3.75	0.56	0.00	0.00	0.89	2.42	5.68	4.91	5.27	5.68	1.16	2.40	32.72
1973	2.30	1.06	5.07	nd	nd	1.56	5.00	2.40	0.34	0.14	0.98	nd	nd
1974	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1975	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1976	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1977	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1978	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1979	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.33	1.49	nd
1980	2.45	1.73	0.86	0.82	1.61	0.62	4.20	3.88	7.00	0.57	0.49	0.26	24.49
1981	0.77	2.54	1.86	1.35	0.73	2.46	4.29	6.97	4.41	1.39	1.95	0.45	29.17
1982	3.84	1.54	0.11	0.19	1.72	1.50	5.11	4.02	5.15	0.40	1.15	4.13	28.86
1983	1.84	1.73	3.01	1.32	1.27	0.84	2.80	2.63	3.84	3.11	3.78	3.06	29.23
1984	0.25	0.24	0.47	0.59	2.26	3.73	2.78	10.94	0.49	5.35	2.22	6.50	35.82
1985	2.31	2.36	1.94	1.59	0.89	2.47	2.84	8.31	4.78	7.53	0.75	0.19	35.96
1986	0.37	1.76	2.60	0.30	2.26	6.72	4.18	8.54	2.30	2.79	5.17	3.14	40.13
1987	0.89	2.25	1.17	1.11	4.52	4.87	nd	nd	nd	nd	nd	nd	nd
Average	1.63	1.52	1.50	0.69	1.03	1.85	5.24	5.10	2.76	1.75	1.10	1.77	26.60

nd = missing

CLOUDCROFT 2, NM (Station: 291929)
From Year 1901 to 1949

Year	Total Precipitation (in) January	February	March	April	May	June	July	August	September	October	November	December	Annual
1901	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	1.70	nd
1902	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1903	nd	4.60	0.90	0.15	nd	nd	nd	2.98	1.85	nd	0.00	0.28	nd
1904	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1905	2.70	4.05	2.12	3.35	0.00	1.12	nd	nd	nd	0.99	5.69	2.54	nd
1906	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1907	6.32	0.43	1.50	0.83	1.82	1.80	4.50	3.86	1.44	4.55	4.00	0.21	31.26
1908	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1909	nd	nd	nd	nd	nd	nd	4.69	3.24	nd	nd	nd	nd	nd
1910	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1911	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1912	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1913	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1914	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1915	1.99	1.72	3.58	nd	0.18	nd	4.77	2.92	5.11	0.00	0.13	1.67	nd
1916	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1917	1.58	2.00	0.21	0.14	1.12	0.72	3.40	4.85	nd	0.04	0.00	0.00	nd
1918	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1919	0.30	1.56	3.67	2.74	0.51	4.65	5.63	2.69	6.99	0.65	2.14	0.51	32.04
1920	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1921	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1922	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1923	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1924	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1925	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1926	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1927	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1928	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1929	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1930	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1931	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

CLOUDCROFT 2, NM (Station: 291929) From Year 1901 to 1949 (cont'd)

Year	Total Precipitation (in)												
	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1932	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1933	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1934	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1935	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1936	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1937	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1938	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1939	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1940	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1941	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1942	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1943	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1944	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1945	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1946	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1947	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1948	nd	nd	nd	nd	nd	2.10	nd	3.70	nd	nd	0.04	5.75	nd
1949	nd	nd	nd	nd	0.15	3.50	6.75	5.65	3.40	3.15	nd	nd	nd
Average	2.57	2.39	1.99	1.44	0.63	2.31	4.95	3.73	3.75	1.56	1.71	1.58	31.65

nd = missing

ESCONDIDA, NM (Station: 293015)
From Year 1914 to 1914

Year	Total Precipitation (in)												
	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1914	0.00	nd	0.21	0.00	0.61	3.57	4.54	nd	nd	nd	nd	nd	nd
Average	0.00	nd	0.21	0.00	0.61	3.57	4.54	nd	nd	nd	nd	nd	nd

nd = missing

LAS CRUCES (AGRICULTURAL COLLEGE), NM (Station: 290131)
From Year 1901 to 1959

Total Precipitation (in)

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1901	0.31	0.95	0.61	0.30	0.00	1.08	2.23	1.35	1.25	2.85	0.98	0.05	11.96
1902	0.02	0.00	0.05	0.00	0.01	0.07	2.16	5.77	1.22	0.00	0.61	0.99	10.90
1903	0.20	0.98	0.37	0.08	0.10	3.65	0.97	1.50	2.43	0.00	0.00	0.01	10.29
1904	0.00	0.11	0.00	0.00	0.05	0.70	1.36	1.24	4.02	1.52	0.50	0.63	10.13
1905	1.01	1.26	2.03	1.89	0.06	0.58	1.83	1.48	3.08	0.83	2.14	0.90	17.09
1906	0.81	0.68	0.13	0.50	0.40	0.00	2.21	0.45	0.31	0.24	2.03	1.04	8.80
1907	0.74	0.00	0.05	0.00	0.22	0.58	0.75	1.42	1.16	0.57	0.93	0.00	6.42
1908	0.38	0.65	0.17	0.27	0.22	0.00	1.99	1.33	0.03	0.22	0.65	0.06	5.97
1909	0.01	0.09	0.89	0.00	0.00	0.55	0.71	1.11	0.92	0.18	0.00	0.48	4.94
1910	0.22	0.02	0.33	0.10	0.00	0.25	1.10	1.46	0.23	0.03	0.11	0.17	4.02
1911	0.27	0.78	0.60	0.32	0.10	0.33	1.36	0.14	1.18	0.30	0.00	0.42	5.80
1912	0.00	0.08	0.30	0.80	0.08	0.12	0.48	5.04	0.70	0.98	0.32	0.30	9.20
1913	0.49	0.80	0.20	1.40	0.01	2.63	1.27	1.33	1.70	0.00	0.80	1.10	11.73
1914	0.10	0.16	0.10	0.00	0.32	1.85	2.08	1.48	0.92	0.54	0.56	3.74	11.85
1915	0.64	0.59	1.23	0.11	0.00	0.00	1.24	1.32	2.11	0.01	0.00	0.12	7.37
1916	0.25	0.18	0.67	0.07	0.97	0.00	0.50	1.28	0.69	2.50	0.52	0.15	7.78
1917	0.19	0.00	0.01	0.01	0.34	0.00	1.31	3.04	0.51	0.00	0.12	0.00	5.53
1918	0.41	0.08	0.00	0.00	0.05	0.69	1.02	1.64	0.05	0.98	1.43	0.88	7.23
1919	0.10	0.00	1.31	0.46	0.05	0.29	1.21	0.90	2.09	0.61	0.78	0.25	8.05
1920	0.72	0.43	0.07	0.00	0.58	1.20	1.05	2.74	0.08	1.30	0.01	0.00	8.18
1921	0.01	0.12	0.04	0.04	0.36	0.58	1.29	1.63	1.68	1.09	0.57	0.23	7.64
1922	0.56	0.00	0.00	0.30	0.38	0.30	0.45	1.05	1.32	0.48	0.49	0.25	5.58
1923	0.16	1.66	0.75	0.17	0.00	0.00	1.32	2.96	0.74	0.38	1.38	0.84	10.36
1924	0.08	0.06	0.47	0.36	0.05	0.00	2.28	0.68	0.45	0.23	0.00	0.17	4.83
1925	0.02	0.26	0.00	0.00	0.32	0.10	1.37	3.46	0.05	1.73	0.00	0.49	7.80
1926	0.49	0.04	1.95	0.55	1.75	0.08	2.36	0.25	3.31	1.79	0.20	1.58	14.35
1927	0.03	0.27	0.64	0.00	0.00	0.70	4.55	1.26	1.64	0.00	0.00	0.38	9.47
1928	0.03	0.69	0.06	0.09	1.79	0.01	1.20	2.14	0.16	2.08	0.98	0.14	9.37
1929	0.02	0.19	0.84	0.06	0.93	0.22	2.16	1.94	0.61	1.09	0.90	0.26	9.22
1930	0.15	0.02	0.02	0.30	0.13	0.29	2.07	1.10	0.62	0.44	1.07	0.67	6.88
1931	0.81	1.14	0.18	0.88	0.06	0.42	2.25	3.48	1.65	0.18	0.83	1.38	13.26

LAS CRUCES (AGRICULTURAL COLLEGE), NM (Station: 290131) From Year 1901 to 1959 (cont'd)

Year	Total Precipitation (in)												
	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1932	0.25	0.68	0.02	0.06	0.65	1.42	0.70	1.56	1.39	1.14	0.00	0.96	8.83
1933	0.25	0.43	0.00	0.26	0.05	1.56	0.45	1.06	0.24	0.22	0.19	0.00	4.71
1934	0.00	0.25	0.45	0.01	0.20	0.03	1.72	0.35	0.40	0.68	0.22	0.31	4.62
1935	0.19	0.29	0.10	0.10	1.07	0.25	0.38	7.41	0.90	nd	0.90	0.66	nd
1936	0.98	0.29	0.13	0.07	0.70	0.14	1.53	1.35	2.12	nd	1.02	0.77	nd
1937	0.01	0.52	0.71	0.00	0.31	0.71	0.67	0.85	1.40	1.42	0.03	0.38	7.01
1938	0.55	0.34	0.15	0.02	0.03	1.02	3.65	0.29	2.53	0.06	0.08	0.55	9.27
1939	0.68	0.05	0.15	0.04	0.00	0.31	0.72	0.75	1.27	0.80	0.72	0.28	5.77
1940	0.11	0.65	0.03	0.22	0.65	1.75	1.46	0.68	1.73	0.73	0.63	0.58	9.22
1941	1.36	0.39	1.26	1.04	0.73	0.90	2.35	2.28	7.53	0.97	0.31	0.48	19.60
1942	0.21	0.48	0.00	0.82	0.00	0.47	1.04	3.04	1.06	1.61	0.00	1.07	9.80
1943	0.48	0.00	0.38	0.04	0.52	1.02	1.30	0.94	1.24	0.00	0.57	1.06	7.55
1944	0.13	0.94	0.19	0.01	0.39	0.62	1.23	2.65	0.63	1.06	1.01	0.41	9.27
1945	0.25	0.05	0.16	0.06	0.00	0.00	1.49	1.92	0.25	1.55	0.00	0.04	5.77
1946	0.82	0.03	0.00	0.01	0.36	0.29	0.14	2.16	2.30	0.12	0.15	0.64	7.02
1947	1.11	0.05	0.48	0.00	0.19	0.49	0.28	2.38	0.00	0.00	0.60	0.50	6.08
1948	0.18	1.43	0.16	0.07	0.04	0.86	0.07	0.46	0.39	0.37	0.00	1.13	5.16
1949	1.85	0.46	0.07	0.06	0.79	0.15	1.14	0.73	2.37	0.88	0.00	0.51	9.01
1950	0.11	0.48	0.00	0.00	0.06	0.25	2.41	0.51	1.14	0.38	0.00	0.00	5.34
1951	0.31	0.38	0.16	0.42	0.02	0.00	1.47	0.96	0.00	0.74	0.08	0.51	5.05
1952	0.00	0.72	0.71	0.56	0.16	1.07	1.11	1.22	0.37	0.00	0.19	0.12	6.23
1953	0.00	0.68	0.41	0.03	0.00	0.28	1.31	0.33	0.00	0.57	0.00	0.20	3.81
1954	0.07	0.30	0.10	0.00	0.82	0.26	0.72	1.34	0.96	0.09	nd	0.00	nd
1955	0.66	0.00	0.39	0.00	0.15	0.08	3.17	0.59	0.01	2.10	0.11	0.00	7.26
1956	0.18	1.04	0.00	0.02	0.00	0.52	0.86	1.35	0.09	0.28	0.00	0.44	4.78
1957	0.32	1.48	0.53	0.02	0.34	0.00	0.81	2.66	0.50	1.82	0.85	0.00	9.33
1958	0.86	1.38	1.84	0.21	0.29	0.39	0.90	3.30	3.42	1.06	0.36	0.00	14.01
1959	0.05	0.17	0.00	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Average	0.35	0.44	0.38	0.22	0.30	0.55	1.40	1.70	1.22	0.74	0.47	0.50	8.30

nd = missing

LAS CRUCES (STATE UNIVERSITY), NM (Station: 298535)
From Year 1959 to 1995

Year	Total Precipitation (in) January	February	March	April	May	June	July	August	September	October	November	December	Annual
1959	nd	nd	nd	0.04	0.72	0.53	0.56	2.81	0.00	0.83	0.05	0.18	nd
1960	0.73	0.16	0.16	0.00	0.01	0.13	2.86	1.00	0.58	0.77	0.08	1.25	7.73
1961	0.74	0.02	0.14	0.00	0.00	2.29	1.10	1.77	1.53	0.03	1.63	0.81	10.06
1962	0.87	0.48	0.02	0.13	0.00	0.25	1.19	0.54	1.79	0.59	0.01	0.52	6.39
1963	0.00	0.92	0.00	0.04	0.00	0.15	1.34	2.22	0.67	0.50	0.27	0.00	6.11
1964	0.02	0.00	0.56	0.12	0.07	0.27	0.51	0.32	1.18	0.03	0.00	0.54	3.62
1965	0.26	0.47	0.20	0.02	0.29	0.85	0.83	1.85	1.73	0.47	0.22	1.10	8.29
1966	0.25	0.25	0.38	0.39	0.01	3.72	0.82	1.86	1.17	0.50	0.40	0.09	9.84
1967	0.00	0.11	0.04	0.00	0.30	1.42	1.79	2.20	1.35	0.00	0.56	0.65	8.42
1968	0.52	0.84	1.09	0.27	0.03	0.15	2.55	3.89	1.28	0.38	1.75	0.42	13.17
1969	0.49	0.20	0.10	0.00	0.41	0.95	3.97	1.59	1.33	1.31	0.15	1.41	11.91
1970	0.00	0.41	0.49	0.00	0.09	0.30	0.75	0.74	0.36	0.11	0.00	0.19	3.44
1971	0.11	0.00	0.00	0.17	0.00	0.00	1.77	0.80	0.57	1.29	0.42	0.64	5.77
1972	0.25	0.00	0.00	0.00	0.11	1.81	1.29	3.23	1.44	3.11	0.28	0.69	12.21
1973	0.93	1.27	0.30	0.00	0.40	1.19	4.12	0.73	0.15	0.02	0.03	0.00	9.14
1974	0.64	0.00	0.39	0.00	0.00	0.06	3.24	3.39	3.12	1.94	0.31	0.74	13.83
1975	0.49	0.36	0.24	0.00	0.48	0.00	0.80	2.57	1.89	0.63	0.23	0.39	8.08
1976	0.31	0.35	0.03	0.56	0.24	0.85	1.81	0.34	1.45	0.87	0.90	0.03	7.74
1977	0.38	0.00	0.28	0.17	0.13	0.17	1.41	2.54	2.10	1.24	0.08	0.24	8.74
1978	0.58	0.35	0.15	0.00	1.02	1.03	0.89	2.60	2.99	1.86	2.59	0.77	14.83
1979	0.76	0.20	0.00	0.39	0.22	0.32	0.81	4.96	0.49	0.00	0.00	1.22	9.37
1980	0.74	0.98	0.26	0.65	0.77	0.00	0.15	1.59	2.07	0.49	0.35	0.00	8.05
1981	0.58	0.03	0.44	0.86	0.68	0.84	0.91	2.66	1.20	0.82	0.65	0.01	9.68
1982	0.87	0.15	0.00	0.00	0.22	0.01	0.57	2.14	1.15	0.75	0.48	1.53	7.87
1983	0.77	0.70	0.22	0.68	0.45	0.20	0.29	0.87	0.14	1.33	1.46	0.17	7.28
1984	0.50	0.00	0.11	0.01	1.09	1.11	0.38	4.82	0.27	2.73	0.40	2.37	13.79
1985	1.28	0.89	0.09	0.59	0.04	0.14	1.39	2.05	2.68	3.19	0.09	0.12	12.55
1986	0.00	0.19	0.22	0.04	0.61	2.08	1.85	1.99	1.76	0.60	1.60	2.06	13.00
1987	0.21	0.22	0.03	0.01	0.05	1.27	0.19	4.78	0.62	0.24	0.31	1.24	9.17
1988	0.18	0.84	0.07	0.31	0.07	0.26	1.55	3.79	2.05	1.09	0.06	0.97	11.24
1989	0.30	0.78	0.67	0.00	0.57	0.00	0.71	3.79	0.76	0.29	0.04	1.03	8.94

LAS CRUCES (STATE UNIVERSITY), NM (Station: 298535) From Year 1959 to 1995 (cont'd)

Year	Total Precipitation (in)												
	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1990	0.51	0.04	0.20	0.88	0.30	0.02	1.87	2.22	1.44	1.02	0.62	0.41	9.53
1991	0.44	0.35	0.69	0.00	0.32	0.12	1.70	5.19	2.23	0.40	0.31	2.91	14.66
1992	1.50	0.04	0.35	0.44	2.03	0.15	0.55	3.19	0.77	0.64	0.06	1.31	11.03
1993	1.82	0.19	0.20	0.02	0.02	0.40	2.28	2.55	0.28	0.73	0.34	0.77	9.60
1994	0.09	0.17	0.13	0.37	0.51	0.11	3.36	0.57	0.80	0.28	0.65	1.11	8.15
1995	0.71	0.60	0.07	0.01	0.11	0.17	2.13	0.47	2.79	0.00	0.21	0.32	7.59
Average	0.52	0.34	0.23	0.19	0.33	0.63	1.46	2.28	1.30	0.84	0.47	0.76	9.46

nd = missing

LULU, NM (Station: 295244)
From Year 1948 to 1961

Year	Total Precipitation (in)												
	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1948	0.80	1.05	0.00	0.35	0.50	1.88	0.30	nd	0.00	0.70	0.00	1.05	nd
1949	0.91	1.13	0.00	0.00	0.20	0.20	3.65	2.16	3.25	3.20	0.40	1.91	17.01
1950	0.54	0.35	0.00	0.20	0.00	7.60	6.16	0.60	2.20	0.00	0.00	0.00	17.65
1951	0.00	0.80	0.50	0.20	1.25	0.40	0.45	0.75	1.22	0.57	0.00	0.80	6.94
1952	0.15	0.00	0.35	0.94	nd	1.85	nd	0.65	0.20	0.00	0.77	0.45	nd
1953	0.00	0.10	0.15	0.38	nd	0.36	2.42	0.82	0.00	1.15	0.30	0.11	nd
1954	0.00	0.00	0.00	0.19	0.70	0.65	0.31	0.81	0.88	0.25	0.00	0.00	3.79
1955	0.00	0.80	0.00	0.25	0.15	0.00	5.36	1.20	0.18	3.95	0.00	0.00	11.89
1956	0.10	nd	0.00	0.00	0.00	nd	2.29	0.32	0.00	0.26	0.00	0.00	nd
1957	nd	0.75	0.74	nd	0.00	0.00	1.00	3.25	0.21	1.87	0.65	0.00	nd
1958	0.40	0.62	1.98	0.49	0.47	1.55	0.69	5.00	2.22	2.35	0.20	nd	nd
1959	0.00	0.00	0.10	0.11	0.55	0.72	0.43	2.03	0.20	0.93	0.37	0.20	5.64
1960	0.84	0.30	0.21	0.00	0.00	0.05	9.44	nd	0.20	1.33	0.13	nd	nd
1961	1.25	0.20	0.20	nd	0.00	0.53	1.10	2.02	nd	nd	nd	nd	nd
Average	0.38	0.46	0.30	0.25	0.31	1.21	2.58	1.63	0.82	1.27	0.21	0.41	10.48

nd = missing

MAYHILL RANGER STATION, NM (Station: 295502)
From Year 1917 to 1976

Year	Total Precipitation (in) January	February	March	April	May	June	July	August	September	October	November	December	Annual
1917	nd	0.29	0.04	0.05	0.80	0.40	3.00	8.12	3.16	0.10	1.10	0.00	nd
1918	1.84	0.32	0.25	0.13	0.25	0.91	3.18	nd	1.00	2.95	1.52	0.84	nd
1919	0.26	0.26	2.75	1.09	0.65	2.09	2.76	1.49	8.43	nd	1.36	0.07	nd
1920	0.87	0.95	0.00	0.03	3.06	4.97	2.44	4.07	2.07	2.55	0.00	0.00	21.01
1921	0.00	0.45	0.45	0.00	1.62	4.08	9.36	5.60	2.68	nd	0.10	0.84	nd
1922	0.59	0.07	0.12	2.61	1.44	1.82	0.68	3.62	2.29	0.90	0.55	0.00	14.69
1923	0.58	1.00	1.04	0.65	0.22	1.32	3.19	5.01	3.02	1.94	1.05	2.83	21.85
1924	0.12	0.57	0.41	0.40	nd	0.20	4.91	2.38	0.09	nd	0.06	0.69	nd
1925	0.32	0.33	0.00	0.01	2.22	1.10	4.73	6.33	nd	1.70	0.00	nd	nd
1926	0.63	0.04	1.90	0.95	3.82	0.67	4.87	4.34	5.02	2.61	1.25	1.55	27.65
1927	0.08	0.10	0.66	0.03	nd	1.40	3.33	2.93	1.88	nd	nd	0.59	nd
1928	0.00	1.47	0.14	0.36	0.95	0.12	3.44	4.21	1.35	3.50	0.75	0.34	16.63
1929	0.27	0.94	1.00	0.00	2.85	0.62	6.15	3.70	0.50	3.24	1.62	0.16	21.05
1930	0.50	0.30	0.45	nd	nd	2.28	nd	nd	nd	5.13	nd	nd	nd
1931	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.58	nd	1.74	nd
1932	1.50	0.93	1.30	0.00	nd	nd	1.92	3.28	6.00	3.15	0.00	0.96	nd
1933	nd	0.80	0.16	nd	0.83	2.60	nd	5.34	2.20	0.00	0.00	0.00	nd
1934	nd	0.16	1.56	nd	0.74	0.28	2.09	3.63	0.00	nd	nd	0.22	nd
1935	0.00	0.90	0.36	nd	nd	1.94	1.95	5.00	6.10	0.30	0.56	0.59	nd
1936	1.61	1.07	0.33	0.46	5.08	1.09	3.92	2.84	7.57	1.64	0.73	0.31	26.65
1937	0.06	1.47	2.10	0.25	2.28	1.99	1.78	2.43	5.93	1.13	0.00	1.03	20.45
1938	2.06	0.68	0.53	0.18	0.21	7.70	3.58	1.77	5.98	1.13	0.40	0.38	24.60
1939	1.04	0.58	2.04	0.30	0.66	1.15	3.03	2.14	2.15	1.09	0.62	0.31	15.11
1940	0.30	1.40	0.07	0.38	3.46	3.62	1.47	4.20	1.91	1.83	0.98	0.52	20.14
1941	1.45	1.09	2.95	1.68	5.31	1.42	4.65	7.08	13.43	3.06	0.40	0.44	42.96
1942	0.52	0.52	0.47	2.38	0.00	2.85	2.74	8.15	4.24	2.74	0.00	2.67	27.28
1943	0.18	0.00	0.20	0.22	1.05	4.30	3.00	2.90	0.93	0.28	0.92	2.70	16.68
1944	0.79	0.65	0.14	0.17	0.60	0.87	4.49	3.98	3.45	0.83	0.99	0.83	17.79
1945	0.74	0.10	0.43	0.10	0.00	0.14	2.00	7.16	1.40	1.72	0.00	0.83	14.62
1946	1.70	0.15	0.79	0.04	0.95	1.30	2.42	2.02	4.27	1.56	0.47	0.41	16.08
1947	1.36	0.08	0.87	0.39	1.17	0.88	1.61	5.14	0.17	0.90	0.85	1.20	14.62

MAYHILL RANGER STATION, NM (Station: 295502) From Year 1917 to 1976 (cont'd)

Total Precipitation (in)

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1948	0.62	1.27	0.59	0.23	2.54	3.66	2.15	1.81	1.03	1.16	0.04	0.78	15.88
1949	3.39	0.19	0.07	1.26	0.42	2.69	5.77	3.79	4.44	2.25	0.03	1.36	25.66
1950	0.02	0.72	0.07	0.12	0.14	2.63	8.72	2.29	5.46	0.81	0.00	0.00	20.98
1951	0.20	0.22	0.88	0.36	0.19	0.26	2.30	1.71	0.45	0.70	0.08	1.25	8.60
1952	0.19	0.74	1.12	0.92	0.69	2.10	3.20	3.78	1.29	0.00	0.89	0.46	15.38
1953	0.19	0.31	0.54	1.14	0.69	1.62	1.89	1.49	0.05	0.89	0.09	1.06	9.96
1954	0.45	0.03	0.18	0.55	2.02	0.46	3.50	3.49	1.86	2.50	0.01	0.46	15.51
1955	1.02	0.16	0.81	0.01	0.17	0.57	9.92	1.53	1.65	1.52	0.06	0.09	17.51
1956	0.18	1.65	0.00	0.04	0.07	0.69	2.60	1.92	0.25	0.52	0.00	0.11	8.03
1957	0.11	0.80	0.73	0.55	0.75	0.36	5.04	7.84	0.51	4.24	1.43	0.00	22.36
1958	1.29	2.14	3.15	0.56	0.95	1.47	2.68	0.91	2.86	2.35	0.14	0.15	18.65
1959	0.00	0.41	0.19	0.17	2.04	2.42	3.56	4.78	0.10	0.40	0.19	0.88	15.14
1960	1.00	0.49	0.33	0.11	0.49	3.08	5.21	2.64	0.56	2.42	0.06	2.27	18.66
1961	0.90	0.19	0.43	0.21	0.22	2.30	1.50	5.61	1.51	0.25	2.82	0.91	16.85
1962	1.21	0.57	0.90	0.78	0.00	1.30	5.64	1.67	5.27	2.13	0.77	1.10	21.34
1963	1.01	0.50	0.01	0.00	0.90	0.65	5.39	3.70	1.74	0.86	0.11	0.02	14.89
1964	0.27	0.95	0.78	0.15	1.23	0.17	2.19	1.42	3.02	0.00	0.16	0.70	11.04
1965	0.11	1.15	0.26	0.77	0.93	4.47	2.95	4.81	4.31	0.38	0.05	1.34	21.53
1966	0.93	0.46	0.74	2.43	0.40	3.50	3.18	5.56	1.63	0.11	0.36	0.04	19.34
1967	0.00	0.50	0.10	0.13	0.76	3.42	2.61	4.48	4.85	0.19	0.73	1.58	19.35
1968	0.83	1.04	1.38	0.22	0.58	1.12	9.58	3.77	0.04	0.97	1.24	0.63	21.40
1969	0.00	0.15	0.52	0.08	1.66	1.04	5.54	9.17	3.81	1.78	0.22	1.43	25.40
1970	0.00	0.33	0.35	0.02	0.71	2.55	2.31	6.31	1.87	0.83	0.00	0.35	15.63
1971	0.34	0.39	0.00	0.89	0.15	1.25	4.20	3.47	3.41	1.44	0.63	0.40	16.57
1972	0.74	0.00	0.00	0.00	0.39	2.91	2.14	6.81	6.42	3.44	0.75	0.90	24.50
1973	nd	1.53	0.49	0.13	1.15	0.75	nd	4.16	0.27	0.10	0.22	0.05	nd
1974	0.50	0.15	0.06	0.23	0.20	0.49	5.06	3.39	9.21	6.40	0.11	2.23	28.03
1975	0.85	0.65	0.73	0.25	0.46	0.20	3.59	3.68	3.22	0.07	0.20	0.43	14.33
1976	0.45	0.43	0.42	1.20	1.75	1.33	5.04	2.65	nd	nd	nd	nd	nd
Average	0.65	0.60	0.66	0.47	1.16	1.78	3.75	3.99	3.00	1.57	0.50	0.77	19.16

nd = missing

MOUNTAIN PARK, NM (Station: 295960)
From Year 1912 to 1995

Year	Total Precipitation (in) January	February	March	April	May	June	July	August	September	October	November	December	Annual
1912	nd	nd	nd	nd	nd	nd	nd	nd	2.28	2.03	0.06	nd	nd
1913	1.13	2.25	1.00	1.91	0.09	2.40	1.42	3.11	2.46	0.12	1.76	2.23	19.88
1914	0.69	0.47	0.60	0.16	0.70	3.40	8.22	3.21	2.92	3.17	0.93	4.23	28.70
1915	2.33	1.97	2.62	3.84	0.05	0.00	2.39	1.90	4.38	0.10	0.25	1.36	21.19
1916	3.26	0.15	1.30	0.69	0.31	0.00	1.46	3.45	1.65	4.25	0.20	0.96	17.68
1917	1.58	0.40	0.00	0.17	1.60	0.26	5.90	4.87	1.44	0.00	0.25	0.00	16.47
1918	2.48	0.86	1.27	0.04	0.00	1.55	4.29	3.71	0.62	4.48	1.98	1.96	23.24
1919	0.05	0.54	2.30	2.38	0.65	1.48	4.39	2.86	5.26	1.02	2.45	0.46	23.84
1920	0.88	1.39	1.51	0.22	0.69	4.88	2.27	2.49	nd	1.71	0.02	0.27	nd
1921	0.33	0.20	1.01	0.04	1.08	2.51	5.02	6.61	3.29	0.35	0.30	0.56	21.30
1922	2.71	0.09	0.34	1.22	1.01	0.67	1.96	1.84	0.79	2.03	1.26	0.32	14.24
1923	1.16	1.90	1.59	0.97	0.52	0.58	2.18	6.87	1.85	0.41	2.49	4.25	24.77
1924	nd	nd	nd	nd	0.49	0.00	3.89	nd	nd	nd	nd	0.44	nd
1925	0.80	0.72	0.00	0.00	1.45	nd	nd	nd	nd	nd	nd	nd	nd
1926	0.00	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1927	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1928	nd	nd	nd	0.05	2.76	0.00	0.84	3.65	0.42	4.01	nd	0.80	nd
1929	0.07	0.47	0.55	nd	2.42	nd	4.32	3.95	nd	nd	nd	nd	nd
1930	nd	nd	nd	nd	0.00	nd	nd	0.00	nd	nd	nd	0.00	nd
1931	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.90	1.52	1.50	nd
1932	nd	1.25	nd	0.25	0.37	0.50	2.50	5.12	0.72	1.27	0.02	0.67	nd
1933	0.85	0.85	0.48	0.00	0.20	6.91	4.38	2.84	1.00	0.08	1.50	0.00	19.09
1934	0.00	0.00	0.35	0.00	nd	0.61	0.03	0.90	nd	0.46	0.67	nd	nd
1935	nd	0.64	0.62	0.08	0.54	0.62	1.85	4.34	3.42	0.00	1.58	0.68	nd
1936	2.49	0.12	0.05	0.14	2.44	nd	2.79	3.06	5.50	0.77	0.50	1.05	nd
1937	0.02	1.82	nd	0.00	1.57	nd	1.48	nd	0.96	2.42	0.06	1.39	nd
1938	1.17	3.00	1.00	0.36	0.42	2.85	nd	1.71	5.48	0.31	1.03	1.52	nd
1939	1.74	nd	1.42	0.33	0.00	nd	4.02	2.31	2.94	2.70	0.86	0.73	nd
1940	0.24	1.15	0.26	0.15	3.61	1.12	0.83	1.85	1.45	1.05	1.37	1.03	14.11
1941	3.32	2.70	2.36	2.40	3.19	nd	5.44	5.45	9.26	4.61	0.62	0.57	nd
1942	0.55	0.36	0.43	2.78	0.00	0.76	3.36	5.86	4.21	1.93	0.00	3.15	23.39

MOUNTAIN PARK, NM (Station: 295960) From Year 1912 to 1995 (cont'd)

Year	Total Precipitation (in) January	February	March	April	May	June	July	August	September	October	November	December	Annual
1943	0.08	0.00	0.54	0.00	0.31	1.87	nd	nd	nd	nd	nd	nd	nd
1944	nd	nd	0.28	0.55	0.20	0.50	3.78	2.09	0.91	0.29	1.59	1.07	nd
1945	0.63	nd	0.19	0.00	0.00	0.00	2.33	nd	0.29	1.36	0.00	0.46	nd
1946	1.86	0.00	1.15	0.22	0.65	0.00	4.50	2.12	1.91	0.96	0.39	0.68	14.44
1947	0.65	0.30	0.23	0.00	0.05	0.30	2.62	3.50	0.57	0.66	1.37	1.60	11.85
1948	0.04	2.11	0.50	0.43	0.88	1.77	2.40	5.13	0.25	1.75	0.66	2.65	18.57
1949	3.34	1.70	0.41	1.00	0.02	1.60	2.33	3.24	3.01	1.51	0.00	2.19	20.35
1950	0.50	0.20	0.05	0.00	0.00	3.00	4.30	0.73	2.67	1.54	0.00	0.00	12.99
1951	1.43	0.96	2.60	1.42	0.25	0.00	2.69	2.61	0.46	2.60	0.80	0.95	16.77
1952	0.27	0.76	1.31	1.09	0.00	3.11	1.70	0.27	0.25	0.00	0.69	0.44	9.89
1953	0.05	1.10	2.10	1.42	0.40	1.87	5.56	2.41	0.10	1.44	0.00	0.67	17.12
1954	0.25	0.10	0.77	0.00	1.40	0.24	2.94	6.05	1.22	1.62	0.00	0.00	14.59
1955	1.50	0.00	1.86	0.00	0.58	0.35	9.76	2.38	0.97	1.60	0.05	0.00	19.05
1956	0.50	0.75	0.00	0.00	0.00	1.69	2.36	3.58	0.00	1.19	0.00	0.30	10.37
1957	0.90	2.38	2.50	0.25	0.00	0.00	3.36	5.45	0.15	4.40	1.54	0.00	20.93
1958	2.39	1.45	4.91	0.96	1.57	1.40	3.16	1.84	4.51	2.69	0.45	0.10	25.43
1959	0.00	1.20	0.00	0.15	0.48	0.65	3.39	5.85	0.00	0.46	0.00	1.05	13.23
1960	4.80	0.35	0.00	0.00	1.16	1.25	7.17	4.22	1.42	0.93	0.00	2.07	23.37
1961	1.70	0.20	2.40	0.00	0.00	3.30	5.46	2.88	3.90	0.00	1.71	4.50	26.05
1962	2.01	0.65	0.25	0.45	0.00	0.00	8.94	1.85	3.41	1.17	0.87	1.25	20.85
1963	1.52	1.27	0.00	0.68	0.57	0.64	2.38	5.97	2.07	1.30	0.63	0.25	17.28
1964	0.33	0.72	0.87	0.40	0.73	0.24	2.96	0.85	3.39	0.00	0.00	nd	nd
1965	2.60	2.02	1.10	0.52	nd	nd	2.90	4.39	3.64	nd	0.31	4.26	nd
1966	0.98	1.58	0.70	0.49	0.45	3.85	2.10	5.23	1.29	0.00	1.02	0.50	18.19
1967	0.00	0.86	0.18	0.00	0.00	1.54	3.73	5.07	2.51	0.00	0.97	2.30	17.16
1968	0.89	1.19	1.45	0.00	nd	nd	3.51	3.71	0.42	0.45	1.80	0.98	nd
1969	1.68	1.47	nd	0.00	1.43	0.00	1.76	6.01	6.43	1.25	0.24	1.68	nd
1970	0.18	0.30	1.61	0.03	0.41	1.28	2.46	1.56	0.98	0.69	0.00	0.77	10.27
1971	0.06	0.61	0.00	1.23	0.11	0.74	3.81	5.59	1.00	4.18	2.20	1.11	20.64
1972	1.44	0.21	0.00	0.00	0.12	2.53	3.74	5.83	4.28	5.47	1.16	1.37	26.15
1973	1.83	0.56	2.51	0.03	0.74	1.91	4.42	1.69	0.41	0.08	0.34	0.04	14.56
1974	2.75	0.62	0.50	0.04	0.00	0.56	5.00	5.22	5.15	5.56	0.80	0.78	26.98

MOUNTAIN PARK, NM (Station: 295960) From Year 1912 to 1995 (cont'd)

Total Precipitation (in)

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1975	1.08	1.12	0.99	0.08	0.41	nd	4.52	2.44	3.99	0.04	1.09	0.54	nd
1976	0.41	1.56	0.28	1.34	3.16	0.71	6.50	1.96	4.30	1.66	0.41	0.00	22.29
1977	1.10	0.97	0.15	2.11	0.55	0.63	4.23	2.63	1.62	1.72	0.80	0.64	17.15
1978	2.88	2.16	1.94	0.31	1.66	1.89	2.06	4.62	2.05	1.65	4.32	3.65	29.19
1979	1.74	2.31	0.57	0.02	1.80	1.61	2.39	5.81	1.78	0.36	0.16	1.44	19.99
1980	1.48	1.64	0.47	0.31	1.56	0.61	1.78	3.47	5.41	0.07	0.16	0.36	17.32
1981	0.79	1.54	1.64	0.36	0.30	2.11	2.19	5.30	1.93	1.49	1.66	0.57	19.88
1982	1.92	1.19	0.03	0.02	1.02	1.15	3.00	3.82	5.79	0.09	0.62	2.87	21.52
1983	1.21	1.79	1.40	1.07	0.55	0.70	2.38	2.71	4.26	2.68	3.47	1.62	23.84
1984	0.16	0.00	0.11	0.55	3.36	3.18	3.08	6.09	0.64	4.55	2.32	5.06	29.10
1985	1.49	1.11	2.07	1.24	0.18	1.92	2.28	6.38	4.86	6.11	0.58	0.22	28.44
1986	0.05	1.60	1.82	0.10	0.95	1.58	2.49	5.08	2.12	2.24	3.60	3.06	24.69
1987	0.59	1.41	1.42	0.73	2.89	1.76	0.66	3.09	3.00	1.31	1.78	0.37	19.01
1988	1.57	0.44	0.51	1.89	0.29	1.33	4.44	6.74	1.17	0.19	0.70	1.89	21.16
1989	0.32	1.05	0.80	0.00	0.36	0.14	5.11	4.26	1.59	0.16	0.12	1.01	14.92
1990	0.64	2.04	1.75	1.25	1.16	0.23	4.88	3.50	4.08	0.88	1.73	1.74	23.88
1991	0.79	2.31	1.11	0.00	0.43	0.85	5.12	6.92	2.68	1.22	1.42	3.61	26.46
1992	2.44	0.47	1.28	1.06	4.72	0.66	2.53	1.40	0.96	0.80	0.48	2.87	19.67
1993	3.01	1.85	0.55	0.50	1.51	1.21	1.69	6.07	0.18	2.95	1.20	0.53	21.25
1994	0.07	0.67	1.51	0.36	1.40	1.90	2.21	0.51	2.42	1.94	3.30	3.27	19.56
1995	2.60	1.51	0.80	0.29	0.14	0.44	4.38	6.74	3.86	0.00	0.69	0.81	22.26
Average	1.21	1.04	0.98	0.56	0.87	1.31	3.42	3.71	2.41	1.54	0.94	1.31	19.94

nd = missing

Newman, NM (Station: 296119)
From Year 1909 to 1933

Year	Total Precipitation (in)												
	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1909	nd	nd	nd	nd	nd	nd	0.74	0.69	1.69	0.60	0.00	0.63	nd
1910	0.00	0.10	0.00	0.00	0.00	1.45	0.29	1.33	0.37	nd	0.75	0.45	nd
1911	0.18	1.77	1.55	1.74	0.00	0.90	2.91	0.48	0.27	0.31	0.10	nd	nd
1912	0.00	nd	0.20	1.32	0.07	0.87	1.32	5.36	4.20	1.00	1.75	0.34	nd
1913	nd	0.57	0.20	0.50	0.00	2.94	0.77	0.35	0.85	0.00	1.16	1.30	nd
1914	0.00	0.27	0.05	0.30	1.75	2.85	7.36	nd	0.55	0.77	1.63	3.12	nd
1915	0.28	0.25	3.66	0.37	0.00	nd	1.68	0.18	3.10	0.00	0.00	0.30	nd
1916	0.70	0.00	0.23	0.00	0.71	0.00	1.60	3.83	nd	0.65	0.00	0.00	nd
1917	0.00	0.00	0.00	nd	0.00	0.00	0.43	3.25	1.20	0.00	nd	0.00	nd
1918	0.30	0.00	0.00	0.00	0.00	1.20	1.04	nd	nd	1.06	1.04	0.96	nd
1919	0.18	0.18	0.52	1.11	0.04	0.71	3.54	0.41	3.54	1.08	0.48	0.05	11.84
1920	1.07	0.80	0.17	0.00	0.67	2.85	0.37	0.61	0.07	1.04	0.06	0.00	7.71
1921	0.10	0.42	0.10	0.00	0.29	1.40	2.94	0.74	1.25	0.35	0.30	0.36	8.25
1922	0.38	0.00	0.00	0.40	0.42	0.00	1.37	2.37	0.23	0.00	0.11	0.22	5.50
1923	0.31	1.10	0.38	0.19	0.00	0.00	0.59	1.98	0.55	0.58	0.55	nd	nd
1924	0.16	0.00	0.70	0.32	0.00	0.20	2.07	0.60	0.73	0.28	0.00	0.00	5.06
1925	0.20	0.00	0.00	0.00	0.99	0.35	2.50	1.17	1.38	1.61	0.00	0.08	8.28
1926	1.06	0.00	0.95	0.32	1.76	0.00	1.55	0.78	2.60	1.13	0.00	1.05	11.20
1927	0.10	0.19	0.25	0.00	0.00	0.00	1.11	0.62	nd	0.00	0.00	0.90	nd
1928	0.00	0.50	nd	0.04	1.22	0.00	1.22	3.25	1.00	1.55	1.18	0.20	nd
1929	0.00	0.05	0.66	0.00	1.10	0.00	2.92	3.44	0.25	1.31	0.41	0.36	10.50
1930	0.12	0.00	0.00	0.19	0.45	1.05	1.42	0.21	0.00	3.66	0.62	0.65	8.37
1931	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.00	1.00	0.23	nd
1932	0.40	0.72	0.16	0.00	0.40	0.07	1.48	1.06	3.39	0.49	0.00	0.24	8.41
1933	0.41	0.05	0.00	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Average	0.27	0.31	0.44	0.32	0.44	0.80	1.79	1.55	1.36	0.75	0.48	0.52	8.51

nd = missing

OROGRANDE 1 N, NM (Station: 296435)
From Year 1904 to 1995

Year	Total Precipitation (in)												
	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1904	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.47	nd
1905	0.97	1.63	nd	1.83	0.00	2.41	3.72	1.30	2.68	0.97	2.56	1.03	nd
1906	0.71	1.14	nd	nd	nd	0.00	1.81	0.75	nd	nd	nd	nd	nd
1907	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1908	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1909	nd	nd	nd	nd	nd	nd	0.17	0.12	0.08	0.04	0.00	0.82	nd
1910	0.00	0.00	0.01	0.00	0.00	1.68	0.30	1.11	0.25	0.20	0.60	0.05	4.20
1911	0.32	1.62	1.24	0.55	0.54	0.97	3.70	0.62	1.10	0.74	0.07	0.45	11.92
1912	0.06	0.14	0.26	0.52	0.00	1.46	0.98	4.33	1.93	1.95	0.18	0.42	12.23
1913	0.39	0.60	0.10	0.44	0.00	1.81	1.00	1.15	1.38	0.00	1.42	0.85	9.14
1914	0.00	0.21	0.05	0.40	1.53	2.47	2.64	2.10	0.76	1.23	1.09	3.80	16.28
1915	0.74	0.70	2.20	1.16	0.02	0.00	4.22	1.00	2.53	0.04	0.00	0.44	13.05
1916	0.74	0.00	0.53	0.04	0.51	0.00	1.11	3.33	0.08	1.58	0.39	0.00	8.31
1917	0.16	0.00	0.25	0.00	nd	0.00	0.86	nd	nd	0.00	0.00	0.00	nd
1918	0.09	0.00	nd	nd	0.00	1.92	0.85	0.66	0.80	0.80	0.43	0.19	nd
1919	0.06	0.00	0.77	0.98	0.20	0.85	1.45	1.30	3.73	0.99	0.25	0.23	10.81
1920	0.49	0.69	0.40	0.00	nd	2.72	0.40	1.21	0.15	1.40	0.04	0.00	nd
1921	0.00	0.22	0.00	0.00	0.10	1.18	1.15	0.80	1.44	0.34	0.30	0.35	5.88
1922	0.65	0.00	0.00	0.25	0.55	0.22	1.16	0.83	0.90	0.93	0.25	0.11	5.85
1923	0.09	1.45	0.69	1.20	0.00	0.20	nd	1.97	0.52	0.41	0.57	0.88	nd
1924	0.24	0.00	0.47	0.25	0.00	0.00	0.70	0.79	0.95	0.29	0.08	0.00	3.77
1925	0.29	0.13	0.00	0.00	0.65	0.15	3.55	2.15	0.95	1.85	0.00	0.55	10.27
1926	0.92	0.00	2.28	0.15	2.11	0.00	5.23	1.65	2.84	1.31	0.00	1.26	17.75
1927	0.00	0.32	0.80	0.00	0.00	1.51	0.16	3.70	2.20	0.00	0.00	0.58	9.27
1928	0.00	0.95	0.00	0.05	1.31	0.00	0.41	3.77	0.60	0.70	0.70	0.40	8.89
1929	0.00	0.72	0.85	0.05	1.31	0.00	2.10	3.37	0.10	3.53	0.88	0.25	13.16
1930	0.45	0.00	0.00	0.68	0.25	0.22	1.47	0.75	0.00	1.01	1.00	0.55	6.38
1931	1.25	1.04	0.10	1.79	0.12	0.00	3.10	4.15	0.65	0.30	1.60	0.68	14.78
1932	0.57	0.40	nd	0.00	0.60	0.30	2.10	1.40	2.90	0.90	0.00	0.30	nd
1933	0.60	0.50	0.00	0.10	nd	2.36	2.75	1.10	0.20	0.40	0.15	0.00	nd
1934	0.08	0.00	0.06	0.00	0.07	0.00	0.07	1.87	0.00	0.33	0.10	0.35	2.93

OROGRANDE 1 N, NM (Station: 296435) From Year 1904 to 1995 (cont'd)

Year	Total Precipitation (in)												
	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1935	0.20	0.44	0.00	0.00	0.22	1.70	0.71	4.03	1.01	0.40	0.85	0.93	10.49
1936	0.47	0.30	0.00	0.10	1.70	0.10	1.10	0.88	3.64	0.40	0.60	0.75	10.04
1937	0.00	0.70	0.85	0.00	1.68	1.00	0.15	1.98	1.55	1.00	0.00	0.52	9.43
1938	1.80	0.46	0.33	0.00	0.08	1.44	0.57	0.68	3.29	0.42	0.02	0.15	9.24
1939	1.04	0.02	0.53	1.40	0.02	0.11	0.94	nd	2.00	1.20	0.75	0.40	nd
1940	0.67	1.40	0.00	0.00	0.60	0.94	2.01	0.88	1.27	1.52	0.83	0.22	10.34
1941	0.47	0.39	1.19	1.24	1.92	1.70	1.30	1.35	6.55	2.05	0.00	0.27	18.43
1942	0.00	0.43	0.31	1.92	0.00	0.00	1.33	1.68	1.21	1.94	0.00	1.20	10.02
1943	0.00	0.00	0.35	0.00	0.82	3.95	1.40	1.35	0.70	0.00	0.80	1.35	10.72
1944	0.93	0.75	0.08	0.00	1.19	0.29	1.90	2.00	1.14	0.74	0.44	0.54	10.00
1945	0.29	0.22	0.00	0.00	0.00	0.02	0.33	1.23	0.18	2.30	0.00	0.18	4.75
1946	0.91	0.00	0.00	0.00	0.14	1.87	0.69	1.43	2.22	1.08	0.12	0.65	9.11
1947	0.45	0.00	0.22	0.06	0.44	0.75	0.29	1.95	0.02	1.49	0.70	0.77	7.14
1948	0.32	0.87	0.00	0.03	1.03	1.49	0.46	2.45	0.52	0.37	0.09	0.83	8.46
1949	1.57	0.55	0.00	0.39	0.32	0.45	1.84	0.59	2.59	1.17	0.00	0.68	10.15
1950	0.16	0.28	0.00	0.00	0.00	0.70	3.81	0.48	0.94	0.93	0.00	0.00	7.30
1951	0.16	0.44	0.38	0.46	0.12	0.14	0.77	0.63	0.21	0.45	0.02	0.41	4.19
1952	0.05	0.53	0.17	1.07	0.33	1.65	1.79	1.76	0.36	0.09	0.66	0.55	9.01
1953	0.00	0.35	1.29	0.79	0.00	0.94	0.57	1.19	0.00	0.88	0.00	0.00	6.01
1954	0.04	0.00	0.00	0.25	0.17	0.43	0.53	2.67	0.52	0.57	0.00	0.05	5.23
1955	0.72	0.00	0.15	0.00	0.00	0.12	7.19	0.40	0.70	2.09	0.00	0.00	11.37
1956	0.00	0.46	0.00	0.00	0.00	0.20	0.34	2.03	0.00	0.26	0.00	0.00	3.29
1957	0.70	0.95	0.45	0.00	0.00	0.00	1.13	1.97	0.00	2.15	0.72	0.00	8.07
1958	0.87	0.20	1.65	nd	0.55	0.78	1.45	1.85	2.98	0.90	0.00	0.00	nd
1959	0.00	0.00	0.00	0.00	0.61	0.58	0.21	2.05	0.00	0.50	0.00	0.42	4.37
1960	0.80	0.00	0.00	nd	0.00	1.07	5.00	nd	nd	nd	nd	nd	nd
1961	nd	0.05	0.40	0.00	0.00	0.64	0.38	1.44	1.22	0.34	1.52	0.56	nd
1962	0.83	0.76	0.04	0.54	0.00	0.33	4.05	0.03	5.94	0.77	0.33	0.39	14.01
1963	0.24	0.36	0.00	0.00	0.04	0.26	0.76	3.19	2.67	1.30	0.58	0.00	9.40
1964	0.13	0.23	0.56	0.00	0.88	0.11	0.93	1.52	0.53	0.10	0.00	0.52	5.51
1965	0.20	0.34	0.17	0.16	0.30	1.67	0.93	2.33	1.17	0.24	0.11	0.83	8.45
1966	0.51	0.26	0.11	1.27	0.11	6.05	0.51	1.94	0.63	0.00	0.17	0.17	11.73

OROGRANDE 1 N, NM (Station: 296435) From Year 1904 to 1995 (cont'd)

Year	Total Precipitation (in) January	February	March	April	May	June	July	August	September	October	November	December	Annual
1967	0.00	0.11	0.00	0.02	0.11	3.67	0.11	3.81	1.97	0.15	0.40	1.11	11.46
1968	0.56	0.70	1.15	0.04	0.00	0.04	2.06	4.27	0.04	0.34	1.03	0.36	10.59
1969	0.12	0.13	0.07	0.00	0.71	0.23	2.91	2.58	0.67	1.13	0.14	0.94	9.63
1970	0.00	0.00	0.17	0.00	0.12	0.55	3.94	0.96	1.50	0.43	0.00	0.11	7.78
1971	0.02	0.00	0.00	0.79	0.00	0.24	2.16	2.62	0.30	0.00	0.00	0.00	6.13
1972	1.10	0.00	0.00	0.00	0.00	0.97	1.41	nd	5.64	nd	nd	0.00	nd
1973	1.44	0.56	0.49	0.00	0.32	0.81	2.88	nd	0.00	0.00	0.05	0.00	nd
1974	0.00	0.00	0.06	0.00	0.10	0.08	6.48	1.40	nd	nd	nd	0.59	nd
1975	0.45	0.40	0.23	0.00	0.79	0.00	1.48	nd	nd	nd	nd	nd	nd
1976	nd	nd	nd	0.43	1.24	0.41	1.75	0.35	0.92	1.37	0.90	0.00	nd
1977	0.59	0.10	0.22	0.73	0.05	0.34	2.36	1.70	0.33	1.44	0.08	0.25	8.19
1978	0.80	0.34	0.10	0.01	1.80	1.22	0.24	2.54	3.69	3.20	2.20	0.67	16.81
1979	1.21	0.47	0.00	0.03	1.74	0.24	2.20	2.83	1.01	0.00	0.01	0.93	10.67
1980	0.66	0.92	0.21	0.22	0.56	0.00	0.35	1.91	5.26	0.89	0.14	0.00	11.12
1981	0.33	0.21	0.36	0.68	0.57	0.45	2.16	3.51	1.68	1.00	0.43	0.06	11.44
1982	0.35	0.16	0.00	0.04	0.41	0.13	0.77	0.54	2.76	2.89	0.75	2.88	11.68
1983	0.11	0.46	0.27	1.01	0.03	1.28	1.27	1.27	0.89	3.54	0.84	0.16	11.13
1984	0.75	0.00	0.00	0.00	1.31	4.72	1.08	6.38	0.48	3.10	0.87	2.16	20.85
1985	1.13	0.34	nd	0.42	0.08	0.83	0.82	2.75	3.45	3.45	0.05	0.07	nd
1986	0.05	0.35	0.33	0.00	0.26	2.08	2.91	2.45	0.87	0.78	2.77	2.31	15.16
1987	0.30	0.23	0.09	0.09	0.62	3.22	1.97	3.44	0.67	0.15	0.63	1.56	12.97
1988	0.31	0.30	0.00	0.32	2.15	0.08	3.88	4.41	1.83	0.28	0.12	0.95	14.63
1989	0.30	0.69	0.40	0.00	1.03	0.12	1.66	3.40	0.67	0.00	0.00	0.87	9.14
1990	0.75	0.15	0.60	0.70	0.42	0.01	1.17	2.20	4.70	0.85	1.02	0.31	12.88
1991	0.56	0.60	0.00	0.00	0.45	0.55	3.22	5.71	3.68	0.40	0.83	5.34	21.34
1992	1.25	0.06	nd	0.93	2.04	3.00	0.25	1.46	1.72	0.27	0.00	1.05	nd
1993	1.66	0.61	0.00	0.00	0.41	0.10	1.90	3.17	0.10	0.27	0.58	0.63	9.43
1994	0.13	0.38	0.27	0.32	0.92	0.09	2.67	2.58	1.01	0.77	0.79	1.10	11.03
1995	0.76	0.69	0.26	0.00	0.00	5.57	1.46	0.87	2.80	0.00	0.00	0.29	12.70
Average	0.46	0.38	0.31	0.32	0.49	0.96	1.70	1.98	1.47	0.91	0.43	0.60	10.11

nd = missing

WHITE SANDS NATL MON, NM (Station: 299686)
From Year 1939 to 1995

Year	Total Precipitation (in)												
	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1939	0.75	0.05	0.42	0.31	0.11	nd	0.97	0.42	1.35	0.94	0.72	0.45	nd
1940	0.28	0.48	0.08	0.31	1.51	0.85	0.77	1.02	0.20	0.25	0.75	0.16	6.66
1941	1.20	0.62	1.25	1.54	1.23	0.01	0.70	2.10	9.68	1.76	0.11	0.69	20.89
1942	0.41	0.25	0.02	2.39	0.05	0.00	0.49	1.32	1.26	1.17	0.00	1.13	8.49
1943	0.02	0.00	0.00	0.00	0.60	1.58	0.50	0.03	0.56	0.08	0.90	1.93	6.20
1944	0.68	0.71	0.10	0.04	0.17	0.36	2.15	1.14	0.64	0.22	0.71	0.85	7.77
1945	0.08	0.00	0.02	0.00	0.00	0.04	0.93	2.68	0.07	0.45	0.00	0.20	4.47
1946	0.75	0.00	0.00	0.00	0.40	1.04	0.76	0.90	1.85	0.25	nd	0.20	nd
1947	1.20	0.00	0.31	0.00	0.04	0.41	1.89	1.30	0.00	0.00	0.56	0.68	6.39
1948	0.50	0.93	0.05	0.00	0.84	1.08	0.37	3.06	0.10	1.39	0.00	1.08	9.40
1949	2.05	0.51	0.00	0.43	0.24	1.03	1.85	1.42	2.94	1.26	0.00	0.24	11.97
1950	0.00	0.04	0.01	0.00	0.00	0.49	2.29	0.69	1.67	1.15	0.00	0.00	6.34
1951	0.34	0.64	0.23	0.55	0.00	0.00	0.00	0.70	0.08	0.59	0.03	0.46	3.62
1952	0.00	0.57	0.16	0.47	0.21	0.69	1.17	0.51	0.21	0.00	0.20	0.31	4.50
1953	0.00	0.64	0.21	0.43	0.05	0.20	1.94	0.50	0.13	0.70	0.00	0.18	4.98
1954	0.03	0.00	0.00	0.03	0.55	0.41	0.71	2.15	0.97	0.58	0.00	0.00	5.43
1955	0.85	0.00	0.48	0.02	0.09	0.32	3.32	0.83	0.72	0.65	0.00	0.00	7.28
1956	0.02	0.21	0.00	0.02	0.00	0.13	0.40	1.50	0.00	0.35	0.00	0.17	2.80
1957	0.26	0.53	0.45	0.31	0.10	0.09	2.97	1.59	0.38	2.39	0.81	0.00	9.88
1958	1.55	0.35	2.65	0.34	0.22	0.54	1.19	1.72	2.34	2.37	0.13	0.00	13.40
1959	0.00	0.36	0.00	0.08	0.51	0.17	0.43	1.84	0.00	0.33	0.00	0.24	3.96
1960	0.56	0.08	0.37	0.00	0.29	1.04	2.84	0.93	0.54	1.01	0.05	2.26	9.97
1961	0.78	0.02	0.55	0.00	0.05	0.49	1.78	0.69	1.39	0.00	1.18	0.64	7.57
1962	0.54	0.40	0.00	0.39	0.00	0.31	4.13	0.21	2.18	0.63	0.42	0.78	nd
1963	0.02	0.18	0.00	0.01	0.00	0.54	1.28	1.15	1.77	1.03	0.04	0.00	6.02
1964	0.00	0.31	0.50	0.07	0.20	0.06	1.45	1.18	0.89	0.00	0.00	0.30	4.96
1965	0.37	0.28	0.36	0.33	0.25	0.35	1.00	1.38	2.95	0.38	0.15	0.94	8.74
1966	0.44	0.26	0.00	0.56	0.11	3.43	1.61	2.17	0.63	0.10	0.04	0.04	9.39
1967	0.00	0.28	0.19	0.00	0.05	1.29	0.81	1.98	0.76	0.00	0.69	1.01	7.06
1968	0.53	0.57	1.06	0.05	0.26	0.06	1.36	2.16	0.03	0.24	1.03	0.21	7.56
1969	0.34	0.20	0.21	0.00	0.35	1.29	2.91	2.18	0.78	1.20	0.10	0.90	10.46

WHITE SANDS NATL MON, NM (Station: 299686) From Year 1939 to 1995 (cont'd)

Year	Total Precipitation (in)												
	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1970	0.01	0.38	0.31	0.05	0.24	0.25	2.26	1.22	0.16	0.50	0.00	0.37	5.75
1971	0.02	0.02	0.00	0.27	0.00	0.28	1.73	2.54	0.36	1.53	0.87	0.66	8.28
1972	0.49	0.00	0.00	0.00	0.09	1.95	1.01	0.98	2.37	3.63	0.57	0.58	11.67
1973	0.39	1.61	1.06	0.00	0.38	0.92	1.24	0.86	0.04	0.19	0.00	0.00	6.69
1974	0.54	0.00	0.16	0.55	0.11	0.03	2.32	1.76	1.66	2.99	0.23	1.06	11.41
1975	0.60	0.35	0.07	0.00	0.07	0.01	2.56	0.42	1.46	0.17	0.24	0.18	6.13
1976	0.08	0.64	0.00	0.47	0.45	0.45	1.56	0.54	1.92	1.31	0.70	0.00	8.12
1977	0.53	0.08	0.45	0.71	0.49	1.73	1.59	0.97	0.04	0.95	0.00	0.26	7.80
1978	0.80	0.62	0.23	0.02	0.92	0.82	0.08	1.76	0.34	2.03	2.71	0.84	11.17
1979	0.71	0.32	0.00	0.00	1.11	0.48	0.56	4.54	0.56	0.00	0.02	1.08	9.38
1980	1.05	0.31	0.03	0.41	0.74	0.02	0.11	2.49	4.68	0.54	0.40	0.07	10.85
1981	1.08	0.19	0.22	0.10	0.68	0.24	1.24	3.39	1.00	0.57	0.43	0.15	9.29
1982	0.34	0.05	0.00	0.00	0.46	0.05	0.85	1.29	4.36	0.02	0.61	1.96	nd
1983	1.11	0.48	0.05	1.16	0.00	0.27	1.36	1.17	0.64	1.55	1.78	0.29	9.86
1984	0.31	0.00	0.32	0.00	0.86	3.82	1.58	2.94	0.24	2.03	1.13	2.77	16.00
1985	1.26	0.42	0.34	0.82	0.50	0.85	1.82	2.69	1.42	4.13	0.05	0.05	14.35
1986	0.02	0.57	0.35	0.01	0.37	1.48	1.05	1.74	1.80	0.97	3.02	1.59	12.97
1987	0.21	0.73	0.60	0.09	0.81	1.95	0.58	3.63	0.56	0.26	0.60	1.76	11.78
1988	0.22	1.37	0.10	0.08	0.18	1.24	1.44	9.78	0.93	0.23	0.00	1.22	16.79
1989	0.24	0.75	0.45	0.00	0.48	0.00	1.97	1.76	2.11	0.00	0.12	0.44	8.32
1990	0.73	0.16	0.73	0.75	0.21	0.47	2.08	1.91	2.03	1.39	0.54	0.54	11.54
1991	nd	0.51	0.53	0.00	0.58	0.12	1.73	2.04	2.24	0.52	0.38	3.88	nd
1992	1.90	0.26	0.50	1.05	3.25	1.46	2.62	1.53	1.18	0.23	0.03	1.58	15.59
1993	1.58	0.29	0.10	0.67	0.06	0.86	1.01	2.51	0.00	0.94	0.71	0.63	9.36
1994	0.27	0.00	0.17	0.27	0.75	0.02	1.09	0.65	0.20	0.54	0.77	0.99	5.72
1995	0.77	0.56	0.08	0.00	0.00	0.80	1.58	1.52	2.88	0.00	0.06	0.15	8.40
Average	0.53	0.35	0.29	0.28	0.39	0.69	1.43	1.72	1.26	0.85	0.43	0.68	8.95

nd = missing

EL PASO, TX (Station: 412797)
From Year 1948 to 1996

Year	Total Precipitation (in)												
	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1948	0.25	0.63	0.04	0.11	0.00	0.96	0.82	1.82	0.03	0.18	0.00	0.86	5.70
1949	1.84	0.22	0.04	0.05	0.39	0.51	1.18	0.43	1.74	1.50	0.00	0.86	8.76
1950	0.29	0.26	0.00	0.00	0.10	0.11	3.57	0.16	1.32	0.94	0.00	0.00	6.75
1951	0.33	0.63	0.59	0.45	0.00	0.00	2.48	0.72	0.04	0.43	0.12	0.68	6.47
1952	0.02	0.96	0.92	1.08	0.46	1.14	1.88	1.06	0.07	0.00	0.23	0.15	7.97
1953	0.00	0.34	0.12	0.71	0.27	0.53	0.99	0.42	0.00	0.65	0.00	0.39	4.42
1954	0.10	0.00	0.09	0.19	1.26	0.23	0.88	2.37	0.95	0.30	0.00	0.02	6.39
1955	0.59	0.05	0.18	0.00	0.26	0.18	3.70	0.70	0.16	0.73	0.15	0.00	6.70
1956	0.35	1.06	0.00	0.05	0.00	1.19	1.10	0.61	0.43	0.01	0.00	0.64	5.44
1957	0.24	0.46	0.33	0.09	0.10	0.02	2.64	4.11	0.11	2.34	0.74	0.02	11.20
1958	0.74	1.11	2.26	0.05	0.40	1.66	1.36	1.14	6.29	1.98	0.20	0.00	17.19
1959	0.21	0.00	0.07	0.15	0.30	0.46	0.40	2.39	0.00	0.58	0.14	0.29	4.99
1960	0.72	0.37	0.21	0.02	0.04	0.76	3.61	0.77	0.01	0.77	0.11	1.73	9.12
1961	0.41	0.00	0.29	0.01	0.00	0.27	2.18	1.40	0.69	0.18	1.63	0.63	7.69
1962	0.94	0.58	0.24	0.10	0.00	0.00	1.82	0.00	3.54	0.55	0.21	0.30	8.28
1963	0.13	0.53	0.00	0.00	0.71	0.05	0.52	1.03	0.64	0.55	0.76	0.00	4.92
1964	0.00	0.00	0.99	0.08	0.02	0.00	0.18	0.76	2.40	0.40	0.00	0.52	5.35
1965	0.19	0.59	0.03	0.01	0.11	0.66	0.17	0.49	2.12	0.18	0.12	0.74	5.41
1966	0.38	0.20	0.00	1.08	0.04	2.67	1.17	1.85	1.79	0.01	0.01	0.04	9.24
1967	0.00	0.04	0.17	0.03	0.05	1.41	0.84	0.54	1.54	0.09	0.23	0.78	5.72
1968	0.47	1.11	0.85	0.10	0.00	0.03	5.53	1.71	0.53	0.11	1.35	0.23	12.02
1969	0.05	0.08	0.17	0.00	0.28	0.00	1.14	0.28	0.43	0.59	0.63	0.69	4.34
1970	0.03	0.55	0.47	0.00	0.71	0.73	1.41	0.41	1.01	0.68	0.00	0.06	6.06
1971	0.19	0.04	0.00	0.42	0.00	0.01	2.34	1.59	0.96	1.07	0.14	0.50	7.26
1972	0.44	0.00	0.00	0.00	0.04	1.62	0.71	2.59	1.60	1.25	0.33	0.42	9.00
1973	1.23	1.69	0.60	0.00	0.29	0.71	2.12	0.73	0.01	0.07	0.08	0.00	7.53
1974	0.27	0.00	0.36	0.12	0.05	0.36	2.21	0.63	6.68	1.90	0.50	0.87	13.95
1975	0.70	0.59	0.19	0.00	0.03	0.00	1.11	0.45	2.18	0.25	0.00	0.71	6.21
1976	0.26	0.52	0.00	0.30	0.74	0.50	3.17	0.23	1.70	1.20	1.20	0.32	10.14
1977	0.57	0.00	0.17	0.09	0.06	0.04	1.09	1.36	0.16	1.65	0.05	0.26	5.50
1978	0.44	0.47	0.07	0.00	0.57	1.46	0.04	2.18	4.14	2.28	0.45	0.47	12.57

EL PASO, TX (Station: 412797) From Year 1948 to 1996 (cont'd)

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
	Total Precipitation (in)												
1979	0.77	0.68	0.00	0.28	0.24	0.03	0.98	2.16	0.41	0.00	0.04	0.25	5.84
1980	0.54	0.73	0.25	0.31	0.08	0.00	0.21	1.76	1.90	0.95	0.54	0.04	7.31
1981	1.10	0.36	0.39	0.65	0.72	0.64	2.08	5.26	0.52	0.53	0.30	0.08	12.63
1982	0.34	0.55	0.00	0.05	0.19	0.18	1.00	0.48	5.28	0.00	0.29	2.61	10.97
1983	0.35	0.60	0.45	1.42	0.05	0.23	0.43	0.97	1.51	1.48	0.34	0.16	7.99
1984	0.31	0.00	0.44	0.01	0.59	3.18	0.69	5.57	0.58	3.12	0.51	1.17	16.17
1985	0.95	0.19	0.59	0.07	0.01	0.10	1.32	1.46	1.47	1.82	0.13	0.05	8.16
1986	0.01	0.39	0.39	0.00	0.83	3.05	2.66	0.70	0.85	0.45	1.42	1.42	12.17
1987	0.29	0.30	0.49	0.32	0.24	2.24	0.64	2.22	0.89	0.15	0.29	2.87	10.94
1988	0.25	0.70	0.10	0.23	0.15	0.03	3.35	3.46	1.52	0.59	0.24	0.44	11.06
1989	0.11	0.72	0.62	0.00	0.65	0.00	1.23	3.06	0.48	0.23	0.00	0.16	7.26
1990	0.29	0.14	0.41	0.25	0.10	0.00	3.96	1.98	3.46	0.58	1.34	0.34	12.85
1991	0.82	0.66	0.10	0.00	0.23	0.01	2.69	2.06	1.82	0.20	0.50	3.29	12.38
1992	1.14	0.16	0.50	0.30	4.22	0.27	0.65	2.11	0.15	0.27	0.28	1.35	11.40
1993	1.34	0.32	0.01	0.12	0.00	1.47	0.95	2.73	1.32	0.17	0.49	0.71	9.63
1994	0.03	0.23	0.37	0.65	0.80	0.67	0.18	0.02	0.03	0.35	0.54	1.61	5.48
1995	0.26	0.88	0.42	0.04	0.01	1.74	0.28	0.76	3.18	0.00	0.26	0.23	8.06
1996	0.11	0.19	0.00	0.49	0.00	2.36	1.97	1.87	1.24	0.00	0.16	0.00	8.39
1997	0.38	0.27	0.64	0.44	nd	nd	nd	nd	nd	nd	nd	nd	nd
Average	0.44	0.42	0.31										

nd = missing

El Paso, Tex.[1] (altitude, 3,762 feet).

1850	......	......	......	......	......	......	......	0.70	0.05	0.60	4.60	1.10	......
1851	0.00	0.90	0.00	0.00	0.70	0.02	1.05	2.49	......	......	......	......	......
1852-53	......	......	......	......	......	......	......	......	......	......	......	......	......
1854	......	......	......	......	......	......	.10	5.71	3.70	1.54	.00	.50	......
1855	.00	.00	......	.00	......	.05	.16	1.12	7.22	1.05	1.25	.00	......
1856	.33	5.55	2.02	.00	.00	.58	2.20	3.38	7.00	.00	.75	.00	21.81
1857	.00	.50	.00	......	.00	.63	1.52	3.73	4.15	2.87	.07	......	......
1858	.25	.15	.06	.00	.00	.19	1.52	2.42	.40	.00	.01	.00	5.00
1859	.10	.10	.00	.01	.01	.03	1.60	.22	1.11	.70	.95	.00	4.83
1860	T.	.24	.00	.01	.00	.30	.53	.08	.18	......	.20	.45	......
1861	.40	.00	......	......	......	......	......	......	......	......	......	......	......
1862-1864	......	......	......	......	......	......	......	......	......	......	......	......	......
1865	......	......	......	......	......	......	......	......	......	......	......	.40	......
1866	.00	.00	......	T.	......	......	......	......	1.45	.00	.15	.11	......
1867	.04	.19	.24	.00	.05	.00	.47	.17	1.29	.30	.02	.07	2.84
1868	.47	.17	.05	......	......	......	......	......	......	......	......	......	......
1869	......	......	......	.00	.40	1.30	.26	5.14	T.	.58	.24	.00	......
1870	.10	......	.00	......	.00	.01	1.43	4.01	.00	.05	T.	.60	......
1871	.59	.00	.20	T.	.33	1.54	1.20	.82	2.64	.01	.00	.28	7.61
1872	1.00	.00	T.	.00	.05	1.83	2.72	.04	.58	.32	.06	1.08	7.68
1873	.64	.00	.30	.36	.07	1.34	.56	.98	.50	.00	1.02	.00	5.77
1874	.37	.34	.06	.52	.00	.26	.50	.96	1.08	1.38	.54	1.23	7.24
1875	.00	.88	.10	.08	T.	.80	1.80	.92	1.87	.00	.00	.03	6.48
1876	.21	.00	.00	T.	T.	.50	T.	4.74	3.76	.00	.25	.00	9.46
1877	......	......	......	......	......	......	......	......	......	......	......	......	......
1878	......	......	......	......	......	......	1.25	2.55	.06	1.02	.06	.11	......
1879	1.57	.83	.18	.07	.00	.08	2.47	.35	.04	.95	.01	.26	6.81
1880	1.01	T.	.30	.10	.00	.00	6.54	3.60	.80	.47	.02	1.53	14.37
1881	.35	.24	.01	.22	1.83	.02	8.18	3.15	1.44	1.45	.50	.78	18.17
1882	.64	.78	.38	.00	.10	.43	1.26	2.82	.40	.00	1.46	.00	8.27
1883	.10	.40	2.09	.10	.02	.04	2.84	1.34	2.51	2.03	.61	.84	12.92
1884	.55	.84	.33	.91	T.	.11	.46	3.98	3.68	5.15	.22	2.07	18.30
1885	.12	.03	.34	.04	1.27	2.63	1.06	.46	.22	.46	.31	.37	7.31
1886	.31	.44	.28	T.	.01	1.03	1.62	1.85	1.16	.80	.52	.01	8.06
1887	.03	.15	.32	.09	.13	.34	.73	1.68	.94	.78	.56	1.01	6.76
1888	.32	1.51	.95	.74	.15	.42	1.39	1.32	.49	1.13	1.32	.05	9.79
1889	.76	.18	.67	.04	.00	.28	1.59	.04	2.64	.35	.55	.00	7.10
1890	.72	.02	.01	.06	T.	.63	.95	3.25	1.81	.41	.35	.28	8.49
1891	.27	.09	.16	.00	.38	.40	.06	.13	.23	T.	T.	.50	2.22
1892	1.25	.57	.30	.11	T.	T.	1.14	.07	.12	.22	.93	.61	5.32
1893	.02	.52	.31	.00	2.28	T.	2.08	3.15	2.08	T.	.02	.42	10.88
1894	.33	.29	.13	.01	.01	.01	1.40	.64	.40	.39	.00	.63	4.24
1895	.65	.17	.05	T.	2.11	.21	2.48	2.01	.28	.88	1.05	.31	10.20
1896	1.63	.14	T.	T.	T.	.60	2.73	1.09	1.48	2.02	.04	.06	9.79
1897	.54	.00	.05	.14	.46	2.17	2.89	2.57	2.73	.77	T.	.09	12.41
1898	.25	.04	.43	.81	.01	.46	1.46	1.00	.50	T.	.16	1.04	6.16
1899	0.06	0.03	0.23	0.88	T.	0.61	3.08	0.91	0.64	0.01	0.64	0.21	7.30
1900	.11	.43	.26	.02	.41	.27	2.38	.43	2.18	1.23	.23	T.	7.95
1901	.35	.68	.47	.47	.05	.30	1.05	.34	.82	2.98	1.05	.03	8.68
1902	.57	.01	.00	.00	T.	.01	3.27	2.85	1.86	.31	.49	.78	10.15
1903	.61	1.09	.15	.54	.29	2.50	1.19	1.73	3.52	.00	.00	.01	11.63
1904	T.	.01	.00	.00	.06	.54	.59	2.24	3.50	3.51	.01	.84	11.30
1905	.86	1.88	1.46	1.38	.03	2.12	2.55	.53	2.29	1.28	2.40	1.02	17.80
1906	.87	1.37	.01	.40	.90	T.	2.02	4.10	1.18	.44	2.50	1.20	14.99
1907	.42	T.	T.	.07	.10	.76	.35	2.50	.96	2.52	.73	T.	8.41
1908	.10	.26	.35	.88	.01	.00	2.07	2.55	T.	.12	.45	.15	6.94
1909	.04	.16	.77	.00	T.	.05	1.62	.51	.60	.02	T.	.56	4.33
1910	.21	.10	T.	T.	T.	1.35	.60	1.18	.24	.02	.03	.30	4.03
1911	.36	.96	.43	.47	.39	2.36	3.43	.45	1.00	.43	.35	.24	10.87
Average	.40	.46	.30	.20	.27	.62	1.69	1.82	1.54	.81	.54	.43	9.08

[1] Fort Bliss till December, 1876.

(after Meinzer and Hare 1915, pp. 82-83)

Precipitation, in inches, at El Paso, Tex., 1878–1953

[From records of U. S. Weather Bureau]

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1878.....	......	......	......	......	......	......	1.25	2.55	0.66	1.02	0.66	0.11	....
1879.....	1.57	0.83	0.18	0.07	T	0.08	2.47	.35	.04	.95	T	.26	6.80
1880.....	1.01	T	.30	.10	0	T	7.54	3.60	.80	.47	.02	1.53	15.37
1881.....	.35	.24	.01	.22	1.83	.02	8.18	3.15	1.44	1.45	.50	.78	18.17
1882.....	.64	.78	.38	0	.10	.43	1.26	2.82	.40	0	1.46	0	8.27
1883.....	.10	.40	2.09	.10	.02	.04	2.84	1.34	2.51	2.03	.61	.84	12.92
1884.....	.55	.84	.33	.91	T	.11	.46	3.98	3.68	5.15	.21	2.07	18.29
1885.....	.12	.03	.34	.04	1.27	2.63	1.06	.46	.22	.46	.31	.37	7.31
1886.....	.31	.44	.28	T	.01	1.03	1.62	1.85	1.16	.80	.52	.04	8.06
1887.....	.03	.15	.32	.09	.13	.34	.73	1.68	.94	.78	.56	1.01	6.76
1888.....	.32	1.51	.95	.74	.15	.42	1.39	1.32	.49	1.13	1.32	.05	9.79
1889.....	.76	.18	.67	.04	0	.28	1.59	.04	2.64	.35	.55	0	7.10
1890.....	.72	.02	.01	.06	T	.63	.95	3.25	1.81	.41	.35	.29	8.49
1891.....	.27	.09	.16	0	.38	.40	.06	.13	.23	T	T	.50	2.22
1892.....	1.25	.57	.30	.11	T	T	1.14	.07	.12	.22	.93	.61	5.32
1893.....	.02	.52	.31	0	2.28	T	2.08	3.15	2.08	T	.02	.42	10.38
1894.....	.33	.29	.13	.01	.01	.01	1.40	.64	.40	.39	0	.63	4.24
1895.....	.65	.17	.05	T	2.11	.21	2.48	2.01	.28	.88	1.05	.31	10.20
1896.....	1.63	.14	T	T	T	.60	2.73	1.09	1.48	2.02	.04	.06	9.79
1897.....	.54	0	.05	.14	.46	2.17	2.89	2.57	2.73	.77	T	.09	12.41
1898.....	.25	.04	.43	.81	.01	.46	1.46	1.00	.50	T	.16	1.04	6.16
1899.....	.06	.03	.23	.88	T	.61	3.08	.91	.64	.01	.64	.21	7.30
1900.....	.11	.43	.26	.02	.41	.27	2.38	.43	2.18	1.23	.23	T	7.95
1901.....	.35	.68	.47	.47	.05	.39	1.05	.34	.82	2.98	1.05	.03	8.68
1902.....	.57	.01	0	0	T	.01	3.27	2.85	1.86	.31	.49	.78	10.15
1903.....	.61	1.09	.15	.54	.29	2.50	1.19	1.73	3.52	0	0	.01	11.63
1904.....	T	.01	0	0	.06	.54	.59	2.24	3.50	3.51	.01	.84	11.30
1905.....	.86	1.88	1.46	1.38	.03	2.12	2.55	.53	2.29	1.28	2.40	1.02	17.80
1906.....	.87	1.37	.01	.40	.90	T	2.02	4.10	1.18	.44	2.50	1.20	14.99
1907.....	.42	T	T	.07	.10	.76	.35	2.50	.96	2.52	.73	T	8.41
1908.....	.10	.26	.35	.88	.01	0	2.07	2.55	T	.12	.45	.15	6.94
1909.....	.04	.16	.77	0	T	.05	1.62	.51	.60	.02	T	.56	4.33
1910.....	.21	.10	T	T	T	1.35	.60	1.18	.24	.02	.03	.30	4.03
1911.....	.36	.96	.43	.47	.39	2.36	3.43	.45	1.00	.43	.35	.25	10.88
1912.....	0	.15	.27	.96	T	1.27	1.11	2.83	1.77	.50	.80	.48	10.14
1913.....	.49	1.26	.29	.14	T	.91	1.13	.54	.60	T	.97	.76	7.09
1914.....	.03	.53	.10	.47	1.23	1.47	4.91	.85	.56	.80	1.13	3.94	16.02
1915.....	1.01	.59	1.34	.20	T	T	2.45	1.37	2.68	.18	.01	.43	10.26
1916.....	.66	.02	.34	.20	.43	0	.59	3.07	.55	1.07	.52	.32	7.77
1917.....	.32	T	.07	T	.14	.36	.41	4.39	.76	T	.04	0	6.49
1918.....	1.20	.01	.08	0	.05	.83	1.52	1.66	.01	1.03	1.04	.78	8.21
1919.....	.08	.20	.62	.65	.14	.27	1.87	.72	3.30	.97	.93	.12	9.87
1920.....	1.06	.83	.22	.03	.03	.99	.84	1.33	.31	.57	T	T	6.21
1921.....	.06	.26	.04	.01	.31	.79	2.13	.35	2.49	.11	.22	.15	6.92
1922.....	.30	T	.16	.28	.36	.05	1.08	.27	1.07	.35	.29	.09	4.30
1923.....	.64	1.41	.33	.04	.01	.09	.20	2.96	.41	.58	.53	.93	8.13
1924.....	.40	.13	.41	.32	T	T	3.00	2.58	.14	.24	.01	.05	7.28
1925.....	.03	.05	T	T	.59	.17	1.40	2.16	1.03	.79	.02	.27	6.51
1926.....	.54	.17	1.49	1.11	.70	.11	3.31	.27	2.24	.89	.15	.75	11.73
1927.....	.05	.18	.28	T	0	.10	2.52	1.34	1.04	.02	T	.72	6.25
1928.....	T	.71	.05	.22	.96	T	1.15	2.69	.04	1.47	.79	.13	8.21
1929.....	T	.29	.21	T	1.51	.54	3.01	1.18	.12	1.60	.33	.50	9.29
1930.....	.17	.16	.03	T	.62	.53	1.33	1.29	.04	.75	.74	.43	6.09
1931.....	.83	.89	.38	2.24	.06	1.34	.73	2.14	1.10	.14	.64	.30	10.79
1932.....	.17	.68	.03	T	1.46	.15	2.28	2.14	2.85	.53	0	.65	10.94
1933.....	.19	.23	T	.09	.04	2.14	1.34	.27	.99	.60	.04	0	5.93
1934.....	.01	.12	.24	.05	.37	.01	.19	.60	.17	.44	.21	.32	2.73
1935.....	.24	.47	.14	.02	.17	.09	.16	1.72	1.24	.14	.92	.34	5.65
1936.....	.57	.06	T	.11	.56	.34	.68	1.94	3.52	.32	1.32	.51	9.93
1937.....	.12	.32	.48	T	.19	1.05	.39	.36	.48	1.71	.22	.91	6.23
1938.....	1.22	.17	.49	T	.02	2.82	.60	.20	2.31	.19	T	.28	8.30
1939.....	.65	.08	.44	.45	.01	T	.60	.91	.90	.93	.75	.19	5.91
1940.....	.54	.41	.02	.02	.43	1.87	1.06	.78	.25	.82	1.25	.31	7.76
1941.....	.46	.46	1.63	1.49	1.23	.18	1.40	2.13	4.19	1.65	.48	.35	15.65
1942.....	.14	.72	.02	1.04	T	.52	.68	3.82	1.03	1.53	0	1.26	10.76
1943.....	.25	0	.07	T	T	1.63	.92	.44	1.36	T	1.53	.82	7.02
1944.....	.45	1.42	.15	T	.30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1945....	0.11	0.17	0.64	T	T	0.03	0.47	0.84	0.12	4.31	0.00	0.05	6.74
1946....	1.23	T	.04	.36	1.23	.20	.71	1.19	1.51	.41	.03	1.31	8.22
1947....	.87	T	.66	.06	.68	.53	.97	1.63	.02	.35	.53	.82	7.12
1948....	.25	.63	.04	.11	T	.96	.82	1.82	.03	.18	T	.86	5.70
1949....	1.84	.22	.04	.05	.39	.51	1.18	.43	1.74	1.50	0	.86	8.76
1950....	.29	.26	T	T	.10	.11	3.57	.16	1.32	.94	0	0	6.75
1951....	.33	.63	.59	.45	T	T	2.48	.72	.04	.43	.12	.68	6.47
1952....	.02	.96	.92	1.08	.46	1.14	1.88	1.06	.07	0	.23	.15	7.97
1953....	0	.34	.12	.71	.27	.53	.99	.42	T	.65	T	.39	4.42
Average..	0.45	0.41	0.33	0.29	0.35	0.63	1.70	1.53	1.16	0.83	0.46	0.51	8.65
Years of record.	75	75	75	75	75	75	76	76	76	76	76	76	75

(after Knowles and Kennedy 1958, Table 2)

APPENDIX C

DESCRIPTIONS OF OTERO AREA SOILS

Table C-1
Classification of Soils
(adapted from USDA Soil Survey of Otero Area, New Mexico:Table 26, 244)

Soil name	Family or higher taxonomic class
Armesa	Fine-loamy, carbonatic, thermic Ustollic Calciorthids
Berino	Fine-loamy, mixed, thermic Typic Haplargids
Bluepoint	Mixed, thermic Typic Torripsamments
Doña Ana	Fine-loamy, mixed, thermic Typic Haplargids
Ector	Loamy-skeletal, carbonatic, thermic Lithic Calciustolls
Holloman	Loamy, gypsic, thermic, shallow Typic Torriorthents
Lozier	Loamy-skeletal, carbonatic, thermic Lithic Calciorthids
Mimbres	Fine-silty, mixed, thermic Typic Camborthids
Nickel	Loamy-skeletal, mixed, thermic Typic Calciorthids
Onite	Coarse-loamy, mixed, thermic Typic Haplargids
Philder	Loamy-skeletal, carbonatic, thermic, shallow Ustochreptic Paleorthids
Pintura	Mixed, thermic Typic-Torripsamments
Prelo	Fine-silty, mixed, thermic Typic Camborthids
Reeves	Fine-loamy, gypsic, thermlc Typic Gypsiorthids
Reyab	Fine-silty, mixed (calcareous); thermic Ustic Torriorthents
Shanta	Fine-loamy., mixed, mesic Cumulic Haplustolls
Tencee	Loamy-skeletal, carbonatic, thermic, shallow Typic Paleorthids
Tome	Fine-silty, mixed (calcareous), thermic Iypic Iorriorthents
Wink	Coarse-loamy, mixed, thermic Typic Calciorthids

Armesa series

The Armesa series consists of deep, well-drained soils that formed in medium textured alluvium and eolian sediment that are high in carbonate. They are on old alluvial fans and terraces. Slope is 0 to 5 percent. Mean annual precipitation is about 14 inches, and the mean annual temperature is about 60 degrees F.

Armesa soils are similar to Jal and La Fonda soi!s. They are near Jerag, Philder, Tencee, Reyab, and Lozier soils. La Fonda soils do not have a calcic horizon. Jal soils are dry in all parts of the moisture control section more than three-fourths of the time (cumulative) that the soil temperature is higher than 41 degrees F and have more than 40 percent calcium carbonate equivalent in the control section (between depths of 10 and 40 inches). Jerag, Philder, and Tencee soils have a petrocalcic horizon at a depth of 20 inches or less. Reyab soils do not have a calcic horizon. Lozier soils are less than 20 inches deep over limestone bedrock.

Typical pedon of the Armesa very fine sandy loam, 0 to 5 percent slopes, in about 300 feet north of County Road 506 where it intersects the southwest corner of sec. 10, T. 21 S., R. 11 E.:

A1— 0 to 3 inches; brown (10YR 5/3) very fine sandy loam, dark yellowish brown (10YR 4/4) moist; weak thin platy structure in upper 1 inch, weak fine granular structure below; soft, very friable, slightly sticky and nonplastic; common very fine, fine, and medium roots, common fine vesicular pores; moderately calcareous; moderately alkaline; abrupt smooth boundary.

B21— 3 to 8 inches; brown (10YR 5/3) sandy clay loam, dark yellowish brown (10 YR 4/4) moist; weak medium subangular blocky structure; slightly hard, firm, slightly sticky and slightly plastic; common very fine and fine and few medium and coarse roots; common fine tubular pores; moderately calcareous; moderately alkaline; clear smooth boundary.

B22ca— 8 to 14 inches; brown (10YR 5/3) sandy clay loam, dark yellowish brown (10YR 4/4) moist; weak medium subangular blocky structure; slightly hard, firm, slightly sticky and slightly plastic; common very fine and fine and few medium and coarse roots; common fine tubular pores; moderately calcareous, about 8 percent calcium carbonate nodules; moderately alkaline; abrupt wavy boundary.

C1ca— 14 to 31 inches; white (10YR 8/2) silty clay loam, very pale brown (10YR 7/3) moist; massive; extremely hard, very firm, slightly sticky and slightly plastic; few fine, medium, and coarse roots; few fine tubular pores; strongly calcareous; moderately alkaline; clear wavy boundary.

C2ca— 31 to 36 inches; very pale brown (10YR 8/3) gravelly silty clay loam, very pale brown (10YR 7/3) moist; massive; extremely hard, very firm, slightly sticky and nonplastic; few fine, medium, and coarse roots; few fine tubular pores; 15 percent gravel; strongly calcareous; moderately alkaline; abrupt wavy boundary.

C3ca— 36 to 60 inches; pink (7.5YR 7/4) gravelly sandy clay loam, strong brown (7.5YR 5/6) moist; massive; soft, very friable, slightly sticky and nonplastic; few coarse roots; few fine tubular pores; 15 percent gravel; moderately calcareous; moderately alkaline.

The A horizon has a value of 5 or 6 dry and 3 or 4 moist. it is very fine sandy loam or loam. The B horizon has value of 5 or 6 dry and 4 or 5 moist. It is sandy clay loam, very fine sandy loam, or loam. The lower part of this horizon has an increase in calcium carbonate equivalent.

The Cca horizon is silt loam, gravelly silt loam, gravelly sandy clay loam, silty clay loam, or gravelly silty clay loam. It is 0 to 20 percent gravel.

Berino series

The Berino series consists of deep, well-drained soils that formed in medium textured upland alluvium and eolian deposits. They are on nearly level to undulating sandy plains and side slopes of pediments. Slope is 0 to 5 percent. Mean annual precipitation is about 9 inches, and the mean annual air temperature is about 63 degrees F.

Berino soils are similar to and near Doña Ana soils They are near Pintura, Tome, and Bluepoint soils. Doña Ana soils are calcareous throughout. Pintura and Bluepoint soils do not have a calcic horizon and do have a sandy control section. Tome soils do not have a calcic horizon and do have a fine-silty control section.

Typical pedon of Berino sandy loam in an area of Doña Ana-Berino association, gently sloping, about 600 yards east of U.S. Highway 54 along the southern boundary of sec. 36, T. 20 S., R. 9 E.:

A1— 0 to 3 inches; light reddish brown (5YR 6/4) sandy loam, reddish brown (5YR 5/4) moist; weak medium granular structure; slightly hard, friable, slightly sticky and nonplastic; few fine and very fine roots;, common fine interstitial and few fine tubular pores; mildly alkaline; clear smooth boundary.

B21t— 3 to 15 inches; reddish brown (5YR 5/4) sandy clay loam, reddish brown (5YR 4/4) moist; weak medium prismatic structure parting to moderate medium subangular blocky; slightly hard, friable, slightly sticky and slightly plastic; few fine and medium roots; common fine and very fine tubular pores; common clay bridging of sand grains, few thin clay films coating pores; mildly alkaline; clear smooth boundary.

B22t— 15 to 27 inches; reddish brown (5YR 5/4) sandy clay loam, reddish brown (5YR 4/4) moist; weak medium prismatic structure parting to weak and moderate medium subangular blocky; hard, firm, sticky and plastic; few fine roots; common interstitial pores; common clay bridging of sand grains and thin clay films in old root channels and some pores; moderately alkaline; clear wavy boundary.

B23tca— 27 to 36 inches; light reddish brown (5YR 6/4) sandy clay loam, reddish brown (5YR 5/4) moist; weak medium prismatic structure parting to weak medium subangular blocky; hard, firm, slightly sticky and slightly plastic; few fine roots; common interstitial and few fine tubular pores; few thin clay films lining pores; strongly calcareous, carbonates in soft masses; moderately alkaline; clear wavy boundary. Cca—36 to 60 inches; pink (7.5YR 7/4) sandy clay loam, light brown (7.5YR 6/4) moist; massive; hard, firm, slightly sticky and nonplastic; few fine tubular pores; strongly calcareous; moderately alkaline.

The solum ranges from 23 to 49 inches in thickness. The solum is 0 to 10 percent coarse fragments. Reaction ranges from mildly alkaline to moderately alkaline. In some pedons as much as 20 inches of coarse textured wind deposited material is on the surface.

The A horizon has hue of 7.5YR or 5YR, value of 5 or 6 dry and 4 or 5 moist, and chroma of 3 or 4. It is very fine sandy loam, fine sandy loam, sandy loam, or light sandy clay loam. The A horizon has been removed in some pedons, leaving the upper part of the B horizon exposed.

The B2t horizon has hue of 7.5YR or 5YR, value of 5 to 6 in the upper part and 5 to 7 in the lower parts dry and 4 or 5 moist, and chroma of 3 or 4. It is sandy clay loam or heavy sandy loam. The lower part of the B2t horizon is calcareous in most pedons (B23tca), but in some pedons only a small amount of calcium carbonate is present above the Cca horizon.

The Cca horizon has hue of 7.5YR or 5YR, value of 6 to 8 dry and 5 to 7 moist, and chroma of 2 to 4. Texture is light sandy clay loam, clay loam, or sandy loam, depending on the amount of carbonate present.

About 50 percent of the soils mapped as Berino soils in the survey area have hue of 7.5YR, which is outside the range defined for the Berino series, but this difference does not affect the use and behavior of the soils.

Bluepoint series

The Bluepoint series consists of deep, somewhat excessively drained soils that formed in coarse textured eolian deposits. They are on coppice dunes on sandy uplands. Slope is 0 to 5 percent. The mean annual precipitation is about 8 inches, and the mean annual air temperature is about 63 degrees F.

Bluepoint soils are similar to and near Pintura soils. They are near Berino, Holloman, Onite, and Wink soils. Pintura soils are less than 10 percent silt plus clay in the control section. Berino and Onite soils have an argillic horizon. Holloman soils are less than 20 inches deep over bedded gypsum. Wink soils have a coarse-loamy control section and have a B horizon.

Typical pedon of Bluepoint loamy fine sand in an area of Bluepoint-Onite-Wink association, nearly level, about 5 miles north of Three Rivers and about 350 yards east of U.S. Highway 54, NW¼ E½ sec. 3, T. 11 S., R. 9 E

A1— 0 to 8 inches; light reddish brown (5YR 6/4) loamy fine sand, reddish brown (5YR 5/4) moist; single grain; loose dry and moist; common fine and medium roots; common very fine interstitial pores; slightly calcareous, lime disseminated; mildly alkaline; gradual smooth boundary.

C1— 8 to 18 inches; light reddish brown (5YR 6/4) loamy fine sand, reddish brown (5YR 5/4) moist; single grain; loose dry and moist; few fine and medium roots; common very fine interstitial pores; strongly calcareous, lime disseminated; mildly alkaline; clear wavy boundary.

C2— 18 to 30 inches; light brown (7.5YR 6/4) loamy fine sand, brown (7.5YR 5/4) moist; massive; slightly hard, very friable; few medium roots; common very fine interstitial pores; moderately calcareous, lime disseminated; moderately alkaline; gradual wavy boundary.

C3— 30 to 60 inches; light brown (7.5YR 6/4) loamy sand, brown (7.5YR 5/4) moist; massive; soft, very friable; few coarse roots; common very fine interstitial pores; moderately calcareous, few fine soft masses of lime; moderately alkaline.

Bluepoint soils have hue of 5YR or 7.5YR, value of 5 to 7 dry and 4 or 5 moist, and chroma of 3 or 4. The control section is loamy fine sand or loamy sand. Small strata of sandy loam are common in some pedons but are normally thin and discontinuous. The soil is calcareous throughout in most pedons but is always calcareous in some stratum. In some areas the soil may be leached of carbonates to a depth of 5 inches.

Doña Ana series

The Doña Ana series consists of deep, well-drained soils that formed in medium and coarse textured eolian material and alluvium. They are on toe slopes of pediments and on sandy uplands. Slope is 0 to 5 percent. The mean annual precipitation is about 9 inches, and the mean annual air temperature is about 63 degrees F.

Doña Ana soils are similar to and near Berino soils and are near Pintura, Bluepoint, and Tome soils. Berino soils are noncalcareous in the upper horizons. Pintura and Bluepoint soils do not have a calcic horizon and have a sandy control section. Tome soils do not have a calcic horizon and have a fine-silty control section.

Typical pedon of Doña Ana fine sandy loam in an area of Pintura-Doña Ana complex, 0 to 5 percent slopes, 5 miles north of Orogrande along bar ditch on U.S. Highway 54, sec. 30, T. 20 S., R. 9E.:

A1— 0 to 3 inches; reddish brown (5YR 5/3) fine sandy loam, reddish brown (5YR 4/4) moist; weak fine granular structure; soft, very friable, nonsticky and nonplastic; few fine and medium roots; few fine tubular pores; strongly calcareous, carbonates disseminated and as soft masses; moderately alkaline; clear smooth boundary.

B21tca— 3 to 10 inches; reddish brown (5YR 5/4) sandy clay loam, reddish brown (5YR 4/4) moist; weak to moderate fine and medium subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; few fine and medium roots; common fine interstitial and few fine tubular pores; common clay bridging of sand grains and few thin clay films in root channels and lining pores; strongly calcareous, lime as soft masses and few nodules; moderately alkaline; clear smooth boundary.

B22tca— 10 to 16 inches; reddish brown (5YR 5/4) sandy clay loam, reddish brown (5YR 4/4) moist; weak medium prismatic structure parting to moderate fine and medium subangular blocky; hard, friable, slightly sticky and slightly plastic; few fine roots; few fine interstitial pores and common fine tubular pores; common clay bridging of sand grains and few thin clay films lining pores and root channels; strongly calcareous, carbonates as filaments and disseminated; moderately alkaline; clear smooth boundary.

B23tca— 16 to 21 inches; reddish brown (5YR 5/4) sandy clay loam, reddish brown (5YR 4/4) moist; weak medium subangular blocky structure; hard, friable, slightly sticky and slightly plastic; few fine roots; few fine tubular pores; few thin clay films lining pores; strongly calcareous, carbonates coating most ped surfaces and few nodules and common soft masses in lower part; moderately alkaline; clear wavy boundary.

Clca— 21 to 37 inches; pinkish gray (5YR 7/2) sandy clay loam, light reddish brown (5YR 6/4) moist; massive; hard, firm, slightly sticky and nonplastic; no roots; common fine tubular pores; strongly calcareous, carbonates almost plugging horizon and as soft masses, nodules, and thick coats; moderately alkaline; clear wavy boundary.

C2ca— 37 to 60 inches; light reddish brown (5YR 6/4), sandy loam, reddish brown (5YR 5/4) moist; massive; hard, very friable, nonsticky and nonplastic; no roots; few fine tubular pores; strongly calcareous, carbonates as soft masses and filaments; moderately alkaline.

The solum ranges from 15 to 30 inches in thickness. Coarse fragments make up less than 5 percent of any one horizon. Patches of desert pavement less than one inch thick cover some pedons.

The A horizon has hue of 7.5YR or 5YR and value of 5 to 7 dry and 3 or 4 moist. Texture is very fine sandy loam, fine sandy loam, sandy loam, or sandy clay loam. In many pedons the A horizon has been removed by erosion and a thin layer of wind-deposited material is on the surface.

The B2t horizon has hue of 7.5YR or 5YR, value of 5 or 6 dry and 4 or 5 moist, and chroma of 3 or 4. It is sandy clay loam in all parts except in a few pedons where the upper part is heavy sandy loam. About one-half of the pedons have a B3ca horizon.

The Cca horizon has hue of 7.5YR or 5YR and value of 6 to 8 dry and 5 to 7 moist.

Ector series

The Ector series consists of shallow, well-drained soils that formed in material weathered from limestone bedrock. Ector soils are on sides of steep limestone hills and on mesas and plateaus dissected by narrow drainageways. Slope is 20 to 50 percent. Mean annual precipitation is about 15 inches, and mean annual air temperature is about 60 degrees F.

Ector soils are similar to and near Deama and Lozier soils. They are also near Kerrick, Pena, and Cale soils. Deama soils have a mean annual soil temperature of less than 59 degrees F. Lozier soils do not have a mollic epipedon and are more dry. Kerrick soils have a petrocalcic horizon. Pena and Cale soils are deep.

Typical pedon of Ector gravelly loam in an area of Ector-Rock outcrop complex, 20 to 50 percent slopes, sec. 15, T. 20 S., R. 15 E.:

A1— 0 to 9 inches; grayish brown (10YR 5/2) gravelly loam, very dark grayish brown (10YR 3/2) moist; moderate medium and fine granular structure; slightly hard, friable, slightly sticky and slightly plastic; common fine and very fine roots; many very fine and fine interstitial pores; 30 percent gravel; strongly calcareous; moderately alkaline; abrupt smooth boundary.

Cca— 9 to 17 inches; light gray (10YR 7/1) extremely gravelly loam, light brownish gray (10YR 6/2) moist; massive; slightly hard, friable, slightly sticky and slightly plastic; few fine and very fine roots; many fine interstitial pores; 70 percent gravel; strongly calcareous; moderately alkaline; abrupt smooth boundary.

R— 17 inches; fractured limestone bedrock; coatings of calcium carbonate in fractures of first several inches of bedrock; few fine roots in fractures.

Limestone bedrock is at a depth of 8 to 18 inches. Content of coarse fragments ranges from 30 to 70 percent. In some pedons there are fractures in the upper few inches of the limestone which are normally filled with precipitated carbonates.

The A horizon has value of 4 or 5 dry. The A horizon is dominantly gravelly loam but in some pedons is clay loam or silt loam containing 30 percent or more coarse fragments.

The Cca horizon is variable in color but normally has value of 7 or 8 dry and 6 or 7 moist.

Holloman series

The Holloman series consists of well-drained soils that formed in gypsiferous sediment of eolian and alluvial origin. They are shallow over gypsum. Holloman soils are on nearly level to gently sloping uplands. Slope is 0 to 5 percent. The mean annual precipitation is about 8 inches, and the mean annual air temperature is about 60 degrees F.

Holloman soils are similar to and near Alamogordo and Yesum soils and are also near Reeves, Tome, and Crowflats soils. Alamogordo and Yesum soils are deep and have a gypsic horizon. Tome and Crowflats soils have a fine-silty control section. Reeves soils are more than 20 inches deep over gypsiferous material and have a calcic horizon.

Typical pedon of Holloman very fine sandy loam, 0 to 1 percent slopes, is about 4 miles east of intersection south of alkali lake, sec. 6, T. 26 S., R. 19 E.:

A1— 0 to 3 inches; very pale brown (10YR 7/3) very fine sandy loam, pale brown (10YR 6/3) moist; weak medium and coarse granular structure; soft, very friable, nonsticky and nonplastic; very few very fine and fine roots; common very fine and fine interstitial pores; strongly calcareous; moderately alkaline; clear smooth boundary.

C1cs— 3 to 13 inches; very pale brown (10YR 7/3) very fine sandy loam, brown (10YR 5/3) moist; massive; soft, very friable, slightly sticky and nonplastic; very few fine and medium roots; common fine and very fine interstitial pores; strongly calcareous; moderately alkaline; clear smooth boundary.

C2cs— 13 to 20 inches; very pale brown (10YR 8/3) gypsum, pale brown (10YR 6/3) moist; massive; soft, very friable, slightly sticky and nonplastic; very few fine and medium roots; few fine and common very fine interstitial pores; strongly calcareous; moderately alkaline; clear smooth boundary.

C3cs— 20 to 60 inches; white (10YR 8/2) gypsum, pale brown (10YR 6/3) moist; massive; slightly hard, very friable, slightly sticky and slightly plastic; common fine and very fine interstitial pores; strongly calcareous; moderately alkaline.

The A horizon has hue of 10YR or 7.5YR, value of 6 or 7 dry and 5 or 6 moist, and chroma of 2 to 4 dry and moist.

The Ccs horizon has hue of 10YR or 7.5YR, value of 6 to 8 dry, and chroma of 2 to 4 dry and moist.

Lozier series

The Lozier series consists of shallow, well-drained soils that formed in material weathered from limestone. These soils are on hillsides, ridgetops, benches, and escarpment caps. Slope is 0 to 50 percent. The mean annual precipitation is about 9 inches, and the mean annual temperature is about 61 degrees F.

Lozier soils are similar to Ector, Deama, and Tencee soils and are near Reakor, Tome, Bluepoint, Nickel, and Tencee soils. Ector and Deama soils have a mollic epipedon, and Deama soils are cooler. Tencee soils have a petrocalcic horizon. Reakor and Tome soils have a fine-silty control section. Bluepoint soils have a sandy control section. Nickel soils have mixed mineralogy and no lithic contact.

Typical pedon of Lozier very gravelly loam in an area of Rock outcrop-Lozier complex, 20 to 65 percent slopes, on the side of a limestone hill, 300 feet north of County Road 506, 3/4 of a mile east of where road crosses west boundary of section 3, NE1/4SE1/4 sec. 3, T. 23 S., R. 16 E.:

A11— 0 to 1 inch; light gray (10YR 7/2) very gravelly silt loam, brown (10YR 5/3) moist; weak thin platy structure; soft, very friable, nonsticky and nonplastic; common very fine roots; common very fine tubular pores; 40 percent limestone gravel and 2 percent limestone cobbles; strongly calcareous; moderately alkaline; clear wavy boundary.

A12— 1 inch to 7 inches; light brownish gray (10YR 6/2) very gravelly loam, brown (10YR 5/3) moist; weak fine and medium subangular blocky and very fine granular structure; soft, friable, slightly sticky and slightly plastic; 45 percent limestone gravel and 5 percent limestone cobbles; strongly calcareous; moderately alkaline; clear wavy boundary.

Cca— 7 to 15 inches; white (10YR 8/2) extremely gravelly silty clay loam, very pale brown (10YR 7/3) moist; massive; hard, friable, slightly sticky and slightly plastic; common very fine roots; common very fine tubular pores; 70 percent limestone gravel and 5 percent limestone cobbles; strongly calcareous; moderately alkaline; abrupt wavy boundary.

R— 15 inches; limestone bedrock; surface is fractured in some places but fractures are not continuous.

The A horizon ranges from 6 to 18 inches in thickness. It rests directly on limestone bedrock in some pedons. Coarse fragments make up 35 to 55 percent of the upper part of the profile and 45 to 80 percent of the lower part.

The A horizon has hue of 10YR or 7.5YR, value of 5 to 7 dry and 4 or 5 moist, and chroma of 2 to 4. It is gravelly loam, very gravelly loam, or very gravelly fine sandy loam. In some pedons, the upper part of the A horizon is very gravelly silt loam.

Mimbres series

The Mimbres series consists of deep, well-drained soils that formed in silty calcareous alluvial sediment weathered from limestone. They are on broad flood plains on the lower parts of long, gently sloping alluvial fans terminating on valley floors. Slope is 0 to 3 percent. The mean annual precipitation is about 9 inches, and the mean annual air temperature is about 61 degrees F.

Mimbres soils are similar to and near Prelo, Tome, Largo, and Reakor soils and are near Reeves, Bluepoint, Jal, and Holloman soils. Prelo soils have gypsum in the C horizon. Tome and Largo soils do not have a cambic horizon. Reakor, Reeves, and Jal soils have a calcic horizon. Bluepoint soils have a sandy control section and do not have a cambic horizon. Holloman soils overlie bedded gypsum at a depth of less than 20 inches.

Typical pedon of Mimbres silt loam in an area of Mimbres-Tome association, nearly level, northeast corner of NW¼ SW¼ sec. 35, T. 18 S., R. 9 E.:

As— 0 to 6 inches; pale brown (10YR 6/3) silt loam, dark brown (10YR 4/3) moist; moderate thick platy structure in upper ½ inch, moderate very fine and fine subangular blocky structure below; slightly hard, very friable, slightly sticky and nonplastic; common fine roots; common very fine and fine vesicular pores; strongly calcareous; moderately alkaline; clear smooth boundary.

B21— 6 to 13 inches; pale brown (10YR 6/3) silty clay loam, dark brown (10YR 4/3) moist; moderate medium and fine subangular blocky structure; common fine and very fine roots; common very fine, fine, and medium vesicular pores; strongly calcareous, moderately alkaline; gradual smooth boundary.

B22— 13 to 25 inches; brown (10YR 5/3) silty clay loam dark brown (10YR 4/3) moist; moderate medium subangular blocky structure; hard, friable, sticky and plastic; few very fine roots; many very fine vesicular pores; strongly calcareous, lime along face of some peds and as threads in pores and old root channels moderately alkaline; gradual smooth boundary.

C1ca— 25 to 42 inches; pale brown (10YR 6/3) silty clay loam, brown (10YR 5/3) moist; weak very fine and fine subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; few very fine roots; many very fine vesicular pores; strongly calcareous, lime as threads and soft masses; moderately alkaline; gradual smooth boundary.

C2ca— 42 to 60 inches; brown (10YR 5/3) silty clay loam, brown (10YR 5/3) moist; massive, slightly hard, firm, sticky and slightly plastic; common very fine vesicular pores; strongly calcareous; moderately fine.

The solum ranges from 22 to 30 inches in thickness The cambic horizon ranges from 19 to 24 inches in thickness.

The A horizon has hue of 10YR or 7.5YR, value of 5 or 6 dry and 4 or 5 moist, and chroma of 2 to 4. It is silt loam, very fine sandy loam, or silty clay loam.

The B2 horizon has hue of 10YR or 7.5YR, value of 4 to 6 dry and 4 or 5 moist, and chroma of 2 to 4. It is silty clay loam, silt loam, or clay loam.

The Cca horizon has hue of 10YR or 7.5YR, value of 5 to 7 dry and 4 or 5 moist, and chroma of 3 or 4. It ranges from heavy silt loam to silty clay loam.

Some pedons mapped as Mimbres soils have hue of in the lower part of the B horizon and in the C horizon, which is outside the range defined for the Mimbres series, but this difference does not affect the use and behavior of the soils.

Nickel series

The Nickel series consists of deep, well-drained soils that formed in very gravelly alluvium mainly from limestone. They are on middle and upper parts of side slopes of pediments and on alluvial fans. Slope is 1 to 30 percent. The mean annual precipitation is about inches, and the mean annual air temperature is about 63 degrees F.

Nickel soils are similar to Aztec, Emot, Ogral, and Lazier soils and are near Tencee, Lozier, Aztec, Reakor, and Ogral soils. Aztec soils have a gypsic horizon. Emot and Ogral soils do not have a calcic horizon. Lozier soils have lithic contact at a depth of less than 20 inches. Tencee soils have a petrocalcic horizon. Reakor soils have a fine-silty control section.

Typical pedon of Nickel gravelly fine sandy loam in an area of Nickel-Tencee association, strongly sloping, ½ mile north of Johnson Tanks on trail in the southwest corner of sec. 8, T. 22 S., R. 18 E.:

A1— 0 to 5 inches; very pale brown (10YR 7/3) gravelly very fine sandy loam, brown (10YR 5/3) moist-weak medium and thick platy and weak coarse granular structure; soft, very friable, nonsticky and nonplastic; common very fine and fine roots; common fine interstitial pores; 20 percent gravel; strongly calcareous, lime disseminated; moderately alkaline; clear wavy boundary.

C1— 5 to 17 inches; pale brown (10YR 6/3) gravelly fine sandy loam, brown (10YR 4/3) moist; weak coarse granular structure; slightly hard, very friable, nonsticky and nonplastic; few medium and common coarse roots; common fine interstitial pores; 25 percent gravel; strongly calcareous, lime disseminated, and in soft masses; moderately alkaline; clear wavy boundary.

C2ca— 17 to 28 inches; white (10YR 8/2) very gravelly sandy loam, light gray (10YR 7/2) moist; massive; slightly hard, friable, slightly sticky and nonplastic; few medium and common coarse roots; common fine interstitial pores; 50 percent gravel; strongly calcareous, lime disseminated and in many soft masses, thick coatings of lime on underside of gravel; moderately alkaline; gradual wavy boundary.

C3— 28 to 60 inches; very pale brown (10YR 7/3) very gravelly sandy loam, brown (10YR 5/3) moist; massive; soft, friable, nonsticky and nonplastic; few medium and common coarse roots; common fine interstitial pores; 75 percent gravel; strongly calcareous; moderately alkaline.

The control section is 35 to 80 percent coarse fragments. Cobbles and/or stones make up 0 to 5 percent of each horizon.

The A horizon has hue of 7.5YR and 10YR, value of 6 or 7 dry and 5 or 6 moist, and chroma of 2 to 4. The texture is gravelly very fine sandy loam, gravelly fine sandy loam, very gravelly loam, or gravelly sandy loam.

The C1 horizon has hue of 10YR or 7.5YR, value of 6 or 7 dry and 4 to 6 moist, and chroma of 2 or 3. Texture is very gravelly sandy loam or gravelly fine sandy loam. The Cca horizon has hue of 7.5YR or 10YR, value of 7 or 8 dry, and chroma of 2 or 3. It is very gravelly sandy loam or very gravelly fine sandy loam with 15 to 25 percent calcium carbonate equivalent.

Some pedons mapped as Nickel soils lack a calcic horizon. This is outside the range defined for the Nickel series, but the difference does not affect the use and behavior of the soils.

Onite series

The Onite series consists of deep, well-drained soils that formed in mixed alluvium. They are on broad alluvial fans. Slope is 0 to 5 percent. Mean annual precipitation is about 9 inches, and the mean annual air temperature is about 63 degrees F.

Onite soils are similar to Berino and Doña Ana soils. They are near Berino, Holloman, Bluepoint, Pintura, and Wink soils. Berino and Doña Ana soils have a fine-loamy control section. Holloman soils are 20 inches or less deep over bedded gypsum. Bluepoint and Pintura soils do not have an argillic horizon and do have a sandy control section. Wink soils do not have an argillic horizon and do have a calcic horizon.

Typical pedon of Onite loamy fine sand in an area of Onite-Pintura association, gently sloping, NE¼ sec. 2, T. 11 S., R. 9 E.:

A1— 0 to 10 inches; brown (7.5YR 5/4) loamy fine sand, dark brown (7.5YR 4/4) moist; weak medium subangular blocky structure; soft, very friable, nonsticky and nonplastic; very few very fine roots; common fine interstitial pores; mildly alkaline; abrupt smooth boundary.

B21t— 10 to 16 inches; brown (7.5YR 5/4) sandy loam, dark brown (7.5YR 4/4) moist; moderate fine and medium subangular blocky structure; slightly hard, very friable, slightly sticky and slightly plastic; very few fine and very fine roots; common fine tubular pores; sand grains have clay bridging; strongly calcareous; mildly alkaline; abrupt smooth boundary.

B22t— 16 to 30 inches; brown (7.5YR 5/4) sandy loam, dark brown (7.5YR 4/4) moist; moderate fine and medium subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; very few very fine and fine roots; common fine tubular pores; sand grains have clay bridging; strongly calcareous; moderately alkaline; clear smooth boundary.

C1— 30 to 38 inches; brown (7.5YR 5/4) sandy loam, dark brown (7.5YR 4/4) moist; moderate fine and medium subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; very few very fine and fine roots; common fine tubular pores; strongly calcareous; moderately alkaline; clear smooth boundary.

C2ca— 38 to 60 inches; light brown (7.5YR 6/4) sandy loam, dark brown (7.5YR 4/4) moist; moderate fine and medium subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; very few fine and medium roots; common fine tubular pores; strongly calcareous; moderately alkaline.

The A1 horizon has hue of 5YR, 7.5YR, or 10YR; value of 3 or 4 moist; and chroma of 3 or 4.

The B2t horizon has hue of 5YR or 7.5YR, value of 5 dry, and chroma of 3 or 4. It is sandy loam or fine sandy loam and has moderate or weak fine, medium, and coarse subangular blocky structure.

The C horizon has hue of 5YR or 7.5YR, value of 5 to 7 dry and 4 to 6 moist, and chroma of 3 or 4. It is sandy loam, fine sandy loam, or loamy fine sand. It contains 0 to 5 percent gravel.

Philder series

The Philder series consists of well-drained soils that formed in alluvium influenced by eolian sediment. They are shallow over indurated caliche. They are on upland fans on pediments. Slope is 0 to 15 percent. Mean annual precipitation is about 14 inches, and the mean annual air temperature is about 60 degrees F.

Philder soils are similar to Jerag and Tencee soils. They are near Armesa, Reyab, Lozier, and Jerag soils. Tencee soils do not have a moisture regime bordering on the ustic. Armesa, Reyab, and Lozier soils do not have a petrocalcic horizon. Lozier soils are in a lithic subgroup. Jerag soils have an argillic horizon.

Typical pedon of Philder very fine sandy loam, 0 to 9 percent slopes, NE¼ SW¼ sec. 20, T. 22 S., R. 13 E.:

A1— 0 to 4 inches; brown (10YR 5/3) very fine sandy loam, dark brown (10YR 3/3) moist; moderate thin platy structure in upper ¼ inch, weak fine and medium granular and weak fine subangular blocky structure below; soft, very friable, slightly sticky and nonplastic; common fine and very fine roots; many very fine and fine pores; extremely hard carbonate fragments less than ½ inch in diameter cover about 30 percent of the surface; slightly calcareous; mildly alkaline; clear smooth boundary.

Blca— 4 to 8 inches; brown (10YR 5/3) sandy clay loam, dark brown (10YR 4/3) moist; weak medium and fine subangular blocky structure; slightly hard, very friable, slightly sticky and slightly plastic; common fine and very fine roots; many fine and very fine pores; strongly calcareous; moderately alkaline; clear smooth boundary.

B2ca— 8 to 12 inches; pale brown (10YR 6/3) gravelly sandy clay loam, dark yellowish brown (10YR 4/4), moist; weak fine and medium subangular blocky structure; slightly hard, very friable, slightly sticky and slightly plastic; common fine roots; many fine and very fine pores; about 30 percent gravel-size indurated carbonate nodules and 2 percent cobbles of the same material; strongly calcareous; moderately alkaline; clear wavy boundary.

Clca— 12 to 18 inches; pale brown (10YR 6/3) extremely gravelly silt loam, yellowish brown (10YR 5/4) moist; massive; soft, very friable, slightly sticky and nonplastic; common fine roots; many very fine pores; 85 percent cobbles and gravel, cobbles make up 5 percent, and gravel-size carbonate nodules make up 80 percent; strongly calcareous; moderately alkaline; abrupt wavy boundary.

C2cam— 18 to 29 inches; white (10YR 8/2) carbonate cemented material, white (10YR 8/2) moist; massive; extremely hard; upper ½ inch is laminar; large cobbles recemented or plugged by carbonates; strongly calcareous; moderately alkaline; clear wavy boundary.

C3ca— 29 to 60 inches; white (10YR 8/2) very gravelly silt loam, very pale brown (10YR 7/3) moist; massive; very hard, firm, slightly sticky and slightly plastic; limestone cobbles and gravel coated with thick masses of carbonates, about 55 percent coarse fragments of which 15 percent is cobble size and 40 percent is gravel size, about half of each in the form of hard petrocalcic material; strongly calcareous; moderately alkaline.

Depth to the petrocalcic horizon ranges from 12 to 20 inches. A desert pavement of coarse fragments of extremely hard carbonate nodules generally less than ½ inch in diameter covers 20 to 45 percent of the surface.

The A horizon has value of 4 or 5 dry and 3 or 4 moist and chroma of 2 or 3. It is very fine sandy loam, fine sandy loam, or loam.

The B2 horizon has value of 4 to 6 dry and 4 or 5 moist. It is sandy clay loam, gravelly sandy clay loam, or gravelly loam and is less than 25 percent clay. This horizon has weak or moderate fine or medium subangular blocky structure.

The C1ca horizon has value of 6 or 7 dry and 4 to 6 moist and chroma of 3 or 4. It is very gravelly silt loam or very gravelly loam. Gravel is petrocalcic material and makes up 50 to 85 percent of the horizon. Cobbles make up 3 to 5 percent.

The Ccam horizon is continuously cemented except for scattered cracks and pipes of nonindurated material. The C3ca horizon has value of 7 or 8 moist and chroma of 2 or 3 dry. It is very gravelly or cobbly silt loam.

Coarse fragments make up 50 to 80 percent of this horizon.

Pintura series

The Pintura series consists of deep, somewhat excessively drained soils that formed in coarse textured eolian material. They are on coppice dunes on uplands of 0 to 5 percent slopes. The dunes have slopes of 20 percent to more than 80 percent. The mean annual precipitation is about 9 inches, and the mean annual air temperature is about 61 degrees F.

Pintura soils are similar to and near Bluepoint soils and are near Berino, Doña Ana, Holloman, Onite, Tome, and Wink soils. Bluepoint soils are calcareous throughout. Berino, Onite, and Doña Ana soils have an argillic horizon. Holloman soils have bedded gypsum at a depth of 20 inches. Tome soils have a fine-silty control section. Wink soils have a calcic horizon.

Typical pedon of Pintura loamy fine sand in an area of Pintura-Doña Ana complex, 0 to 5 percent slopes, 200 feet west of the Escondida Siding, northwest corner of NW¼ sec. 10, T. 20 S., R. 9 E.:

A1— 0 to 12 inches; light reddish brown (5YR 6/4) loamy fine sand, reddish brown (5YR 4/4) moist; single grain; loose dry and moist; slightly calcareous; mildly alkaline; gradual wavy boundary.

C1— 12 to 30 inches; light reddish brown (5YR 6/3) fine sand, reddish brown (5YR 4/4) moist; massive; soft, very friable, nonsticky and nonplastic; slightly calcareous; mildly alkaline; gradual wavy boundary.

C2— 30 to 60 inches; light reddish brown (5YR 6/4 loamy fine sand, reddish brown (5YR 4/4) moist; massive; soft, very friable, nonsticky and nonplastic; slightly calcareous; mildly alkaline.

The A horizon has value of 4 to 6 dry and 3 to 5 moist and chroma of 3 or 4. It is loamy fine sand or fine sand.

The C horizon has value of 4 to 6 dry and 3 to 5 moist and chroma of 3 or 4. The C horizon is loamy sand, loamy fine sand, or fine sand. It ranges from noncalcareous to moderately calcareous.

Prelo series

The Prelo series consists of deep, well-drained soils that formed in fine textured alluvium weathered from shale and siltstone. Prelo soils are on broad flood plains and lower parts of alluvial fans and pediments terminating on the basin floor. Slope is 0 to 3 percent. The mean annual precipitation is about 9 inches, and the mean annual air temperature is about 61 degrees F. Prelo soils are similar to Largo, Prelo Variant, Tome, Reakor, Reeves, and Mimbres soils and are near Alamogordo, Prelo Variant, Mimbres, Aztec, Largo, Tome, and Reeves soils. Prelo Variant soils have a fine loamy control section. Largo and Tome soils do not have a cambic horizon. Reakor and Reeves soils have a calcic horizon. Mimbres soils do not have gypsum in the C horizon. Alamogordo and Aztec soils have a gypsic horizon.

Typical pedon of Prelo silt loam, 0 to 3 percent slopes, in the southeast corner of the SE¼ SW¼ sec. 4, T. 16 S., R. 10 E.:

A11— 0 to 4 inches; reddish brown (5YR 5/4) silt loam, dark reddish brown (5YR 3/4) moist; weak very thin and thin platy structure in upper one inch, weak medium platy structure below; soft, friable, sticky and plastic; very few very fine and fine roots; common fine vesicular pores; moderately calcareous; moderately alkaline; clear smooth boundary.

A12— 4 to 8 inches; reddish brown (5YR 4/4) silty clay loam, dark reddish brown (5YR 3/4) moist; moderate medium and fine subangular blocky structure; slightly hard, friable, sticky and plastic; very few fine roots; few fine tubular pores; moderately calcareous; moderately alkaline; clear smooth boundary.

B21— 8 to 16 inches; reddish brown (5YR 4/4) silty clay loam, dark reddish brown (5YR 3/4) moist; moderate medium and fine subangular blocky structure; slightly hard, friable, sticky and plastic; very few fine roots; common fine tubular pores; few fine irregularly shaped soft masses and filaments of gypsum; strongly calcareous, lime disseminated; moderately alkaline; clear smooth boundary.

B22— 16 to 24 inches; reddish brown (5YR 4/4) silty clay loam, dark reddish brown (5YR 3/4) moist; moderate medium subangular blocky structure; slightly hard, friable, sticky and plastic; few fine roots; common fine tubular pores; few fine irregularly shaped soft masses and filaments of gypsum; strongly calcareous, lime disseminated; moderately alkaline; clear smooth boundary.

B23— 24 to 32 inches; reddish brown (5YR 4/4) silty clay loam, dark reddish brown (5YR 3/4) moist; weak medium and fine subangular blocky structure; slightly hard, friable, sticky and plastic; common fine tubular pores; few fine irregularly shaped soft masses and filaments of gypsum; strongly calcareous, lime disseminated; moderately alkaline; clear smooth boundary.

C1cs— 32 to 45 inches; reddish brown (5YR 4/4) silty clay loam, dark reddish brown (5YR 4/4) moist; weak medium and fine subangular blocky structure; slightly hard, friable, sticky and plastic; common fine tubular pores; common fine irregularly shaped soft masses and filaments of gypsum; strongly calcareous, lime in small soft masses; moderately alkaline; clear smooth boundary.

C2— 45 to 60 inches; reddish brown (5YR 5/4) silty clay loam, dark reddish brown (5YR 3/3) moist; massive; slightly hard, firm, sticky and plastic; common fine tubular pores; common fine irregularly shaped soft: masses and filaments of gypsum and a few medium gypsum crystals; calcareous, lime in small soft masses; moderately alkaline.

The solum ranges from 25 to 40 inches in thickness. Gypsum content ranges from 3 to 5 percent in the B horizon and from 5 to 20 percent in the C horizon. Reaction ranges from mildly alkaline to moderately alkaline.

The A horizon has hue of 5YR or 7.5YR, value of 3 to 6 dry and 3 or 4 moist, and chroma of 3 or 4. It is silt loam, silty clay loam, fine sandy loam, or sandy loam.

The B horizon has hue of 7.5YR or 5YR, value of 3 to 5 dry and 3 or 4 moist, and chroma of 3 or 4 moist. It is silty clay loam, clay loam, or silt loam and averages 25 to 35 percent clay. The lower part of the B horizon ranges to clay loam in some pedons.

The C horizon has value of 3 to 6 dry and 3 or 4 moist. It is silty clay loam, silt loam, or clay loam. Gypsum content increases with depth, but there are no gypsum beds above a depth of more than 90 inches.

Prelo Variant

The Prelo Variant consists of deep, well-drained soils that formed in mixed alluvium from Permian red beds. They are on the lower parts of side slopes of pediments. Slope is 0 to 3 percent. Mean annual precipitation is about 9 inches, and the mean annual air temperature is about 61 degrees F.

Prelo Variant soils are similar to Emot, Ogral, and Prelo soils. They are near Alamogordo, Largo, and Prelo soils. Emot, Largo, and Ogral soils do not have a cambic horizon. Prelo soils do not have gravel in the profile. Alamogordo soils have a gypsic horizon.

Typical pedon of Preio Variant silt loam in an area of Prelo-Prelo Variant complex, 0 to 3 percent slopes, NE¼ NE¼ sec. 3, T. 16 S., R. 9 E.:

A1— 0 to 7 inches; reddish brown (5YR 4/4) silt loam dark reddish brown (5YR 3/3) moist; moderate fine and very fine subangular blocky structure; hard, friable, slightly sticky and slightly plastic; very few very fine roots; very few very fine pores; common fine filaments of gypsum; strongly calcareous; moderately alkaline; abrupt smooth boundary.

B21— 7 to 13 inches; reddish brown (5YR 4/4) silt loam, dark reddish brown (5YR 3/4) moist; moderate medium, fine, and very fine subangular blocky structure; slightly hard, very friable, slightly sticky and slightly plastic; few very fine roots; few very fine tubular pores; few fine filaments of gypsum; strongly calcareous; moderately alkaline; abrupt smooth boundary.

B22cs— 13 to 22 inches; reddish brown (5YR 4/4) silty clay loam, dark reddish brown (5YR 3/4) moist; massive; hard, friable, sticky and plastic; very few.

Reeves series

The Reeves series consists of deep, well-drained soils that formed in medium textured calcareous and gypsiferous alluvium. Reeves soils are on broad valley floors and alluvial toe slopes. Slope is 0 to 2 percent. Mean annual precipitation is about 9 inches, and the mean annual air temperature is about 64 degrees F.

Reeves soils are similar to and near Holloman soils. They are near Alamogordo, Crowflats, Tome, and Prelo soils. Holloman soils are less than 20 inches deep over gypsum. Prelo soils are less than 15 percent fine sand or coarser particles. Alamogordo soils have a coarse loamy control section. Crowflats and Tome soils do not have a gypsic horizon and do not have gypsic mineralogy.

Typical pedon of Reeves very fine sandy loam, 0 to 1 percent slopes, about 1 mile south of intersection of U.S. Highways 70 and 54, SW¼ SW¼ NW¼ sec. 12, T. 17 S., R. 9 E.:

A1— 0 to 8 inches; pale brown (10YR 6/3) very fine sandy loam, dark brown (10YR 4/3) moist; moderate medium platy structure; slightly hard, very friable, slightly sticky and slightly plastic; few fine and medium roots; common very fine and fine interstitial pores; strongly calcareous; moderately alkaline; clear smooth boundary.

B21— 8 to 13 inches; brown (10YR 5/3) silt loam, dark brown (10YR 4/3) moist; moderate medium and fine subangular blocky structure; slightly hard, very friable, slightly sticky and slightly plastic; few fine and medium roots; common very fine tubular pores; strongly calcareous; moderately alkaline; clear smooth boundary.

B22ca— 13 to 20 inches; pale brown (10YR 6/3) silt loam, dark brown (10YR 4/3) moist; weak medium and fine subangular blocky structure; slightly hard, very friable, slightly sticky and slightly plastic; common very fine and fine roots; common very fine tubular pores; strongly calcareous; moderately alkaline; clear smooth boundary.

C1ca— 20 to 32 inches; very pale brown 10YR 7/3) sandy clay loam, brown (10YR 5/3) moist; massive; slightly hard, very friable, slightly sticky and slightly plastic; strongly calcareous; moderately alkaline; clear smooth boundary.

C2csca— 32 to 38 inches; light brown (7.5YR 6/4) fine sandy loam, brown (7.5YR 5/4) moist; soft, very friable, nonsticky and nonplastic; few very fine tubular pores; strongly calcareous; moderately alkaline; clear smooth boundary.

C3csca— 38 to 60 inches; pink (7.5YR 7/4) silt loam, light brown (7.5YR 6/4) moist; massive; slightly hard, very friable, slightly sticky and slightly plastic; few very fine tubular pores; strongly calcareous; moderately alkaline.

The depth to the gypsic horizon ranges from 20 to 40 inches.

The A horizon has hue of 7.5YR or 10YR, value of 5 or 6 dry, and chroma of 2 to 4. It is very fine sandy loam or silt loam.

The B2 horizon has hue of 7.5YR or 10YR, value of 4 to 6 dry and 3 or 4 moist, and chroma of 2 to 4. It is silt loam, clay loam, or loam but in some pedons contains a few thin lenses of very fine sandy loam in the upper part.

The C1ca horizon has hue of 7.5YR or 10YR, value of 6 to 8 dry and 5 to 7 moist, and chroma of 3 or 4. It is sandy clay loam, clay loam, or loam. The Ccs horizon has hue of 7.5YR or 10YR, value of 6 to 8 dry and 5 to 7 moist, and chroma of 2 or 4 dry and 4 moist. It is silt loam, loam, or fine sandy loam.

Reyab series

The Reyab series consists of deep, well-drained soils that formed in alluvium weathered mainly from limestone. They are on alluvial bottoms, terraces, and fans on broad uplands. Slope is 0 to 5 percent. The mean annual precipitation is about 14 inches, and the mean annual air temperature is about 60 degrees F.

Reyab soils are similar to Crowflats, Largo, and Tome soils and are near Armesa, Jerag, Lozier, and Philder soils. Crowflats soils have highly stratified layers and decrease irregularly in organic matter content with depth. Largo and Tome soils are dry in all parts of the moisture control section three-quarters or more of the time (cumulative) that the soil temperature at a depth of 50 cm is 5 degrees C or higher. Largo soils have hue of 7.5YR or redder throughout. Armesa soils have a calcic horizon between depths of 10 and 20 inches. Jerag soils have an argillic horizon and a petrocalcic horizon at a depth of less than 20 inches. Lozier soils have a calcic horizon and are less than 20 inches thick over limestone bedrock. Philder soils have a petrocalcic horizon at a depth of less than 20 inches.

Typical pedon of Reyab loam in an area of Reyab-Armesa association, gently sloping, on Otero Mesa about 11.8 miles south on County Road 506 from the guard station at the east gate of the McGregor Missile Range and 250 feet west of road, NW¼ NW¼ sec. 15, T. 24 S., R. 13 E.:

A1— 0 to 4 inches; light gray (10YR 7/2) loam, dark brown (10YR 3/3) moist; weak medium platy and weak medium and fine subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; few fine and very fine roots; few very fine tubular pores; strongly calcareous, lime disseminated; moderately alkaline; clear smooth boundary.

B21— 4 to 12 inches; light gray (10YR 7/2) silt loam, dark brown (10YR 4/3) moist; weak medium and fine subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; few fine and very fine roots; few very fine tubular pores; strongly calcareous, lime disseminated; moderately alkaline; gradual smooth boundary.

B22— 12 to 25 inches; very pale brown (10YR 7/3) silt loam, brown (10YR 5/3) moist; weak coarse and medium subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; few fine and very fine roots; few very fine tubular pores; strongly calcareous, lime disseminated; moderately alkaline; gradual smooth boundary.

C— 25 to 60 inches; very pale brown (10YR 7/3) silt loam, brown (10YR 5/3) moist; massive; slightly hard, friable, slightly sticky and slightly plastic; few fine and very fine roots; few very fine tubular pores; strongly calcareous, lime disseminated; moderately alkaline.

The solum is 20 to 40 inches thick. Depth to bedrock is 60 inches or more.

The A horizon is light gray, light grayish brown, grayish-brown, pale brown, and brown; it has value of 5 to 7 dry and chroma of 2 or 3. This horizon is loam or silt loam.

The B2 horizon is light gray, very pale brown, grayish brown, light brown, and brown; it has hue of 10YR or 7.5YR, value of 5 to 7 dry, and chroma of 2 to 4. This horizon is silt loam or light silty clay loam. Structure is weak to moderate.

The C horizon is very pale brown, light gray, grayish-brown, pale brown, or light brown; it has hue of 10YR or 5YR, value of 5 to 7 dry, and chroma of 2 to 4. This horizon is silt loam or light silty clay loam.

Shanta series

The Shanta series consists of deep, well-drained soils that formed in mixed alluvium. Shanta soils are on flood plains and valley bottoms. Slope is 0 to 2 percent. Mean annual precipitation is about 15 inches, and the mean annual air temperature is about 56 degrees F.

Shanta soils are similar to Gabaldon, Ruidoso, Pena, and Cale soils. They are near Gabaldon, Reeves Variant, and La Fonda soils. Gabaldon and Cale soils are less than 15 percent fine sand or coarser particles in the control section. Ruidoso soils are more than 35 percent clay in the control section. Pena soils have a calcic horizon and contain more than 35 percent gravel. Reeves Variant soils have a gypsic horizon. La Fonda soils do not have a mollic epipedon.

Typical pedon of Shanta loam in an area of Shanta-Gabaldon association, nearly level, SE¼ sec. 7, T. 11 S., R. 10 E.:

A1— 0 to 13 inches; dark brown (10YR 4/3) loam, very dark grayish brown (10YR 3/2) moist; moderate coarse, medium, and fine subangular blocky structure; slightly hard, friable, sticky and plastic; common fine and very fine roots; common fine tubular pores; moderately calcareous; mildly alkaline; gradual smooth boundary.

C1— 13 to 27 inches; dark brown (10YR 4/3) silt loam, very dark grayish brown (10YR 3/2) moist; moderate medium and fine subangular blocky structure; slightly hard, friable, sticky and plastic; common fine and very fine roots; common fine tubular pores; moderately calcareous; moderately alkaline; clear smooth boundary.

C2— 27 to 60 inches; brown (10YR 5/3) sandy loam, dark grayish brown (10YR 4/2) moist; weak coarse and medium subangular blocky structure; slightly hard, very friable, sticky and plastic; common fine and very fine roots; common fine tubular pores; moderately calcareous; moderately alkaline.

The A horizon has value of 4 or 5 dry and 2 or 3 moist and chroma of 2 or 3.

The C horizon has value of 4 or 5 dry in the upper part and 5 or 6 dry in the lower part and chroma of 2 to 4. Texture is normally silt loam, sandy loam, loam, or clay loam.

About 25 percent of the soils mapped as Shanta soils in this survey area have regular decrease in organic matter, which is not within the definition of the series, but this difference does not affect the use and behavior of the soils.

Shanta Variant:

The Shanta Variant consists of deep, well-drained soils that formed in mixed alluvium. They are on drainageways of dissected terraces and valley bottoms. Slope is 0 to 2 percent. Mean annual precipitation is about 12 inches, and the mean annual air temperature is about 60 degrees F.

Shanta Variant soils are similar to Gabaldon, Pena, Ruidoso, Shanta, and Cale soils. They are near Espy, Ector, and Lozier soils. Gabaldon soils have an irregular decrease in organic carbon content and have a mesic temperature regime. Pena soils have a calcic horizon and contain more than 35 percent gravel in the control section. Ruidoso soils are 35 percent or more clay in the control section and have a mesic temperature regime. Shanta soils have an irregular decrease in organic carbon content, are 15 percent or more fine sand or coarser particles, and have a mesic temperature regime. Cale soils have an argillic horizon and a mesic temperature regime. Espy soils have a petrocalcic horizon at a depth of less than 20 inches. Ector and Lozier soils have limestone bedrock at a depth of less than 20 inches.

Typical pedon of Shanta Variant silt loam in an area of Espy-Shanta Variant association, gently sloping, SW¼ SW¼ sec. 15, T. 21 S., R. 16 E.:

A11— 0 to 9 inches; brown (10YR 5/3) silt loam, very dark grayish brown (10YR 3/2) moist; weak moderate and fine subangular blocky structure; soft friable, sticky and plastic; common fine and medium roots; common fine tubular pores; mildly alkaline; clear smooth boundary.

A12— 9 to 12 inches; brown (10YR 4/3) silt loam, very dark grayish brown (10YR 3/2) moist; weak fine subangular blocky structure; hard friable, sticky and plastic; common fine roots; common fine tubular pores; slightly calcareous; mildly alkaline; abrupt smooth boundary.

B21— 12 to 28 inches; brown (10YR 4/3) silt loam, dark yellowish brown (10YR 3/4 moist; moderate fine and medium angular blocky structure; hard, friable, sticky and plastic; few fine and very fine roots; common fine tubular pores; slightly calcareous; moderately alkaline; gradual smooth boundary.

B22ca— 28 to 60 inches; brown (10YR 4/3) silt loam, dark yellowish brown (10YR 3/4) moist; moderate fine and medium angular blocky structure; hard, friable, sticky and plastic; few fine and very fine roots; common fine tubular pores; slightly calcareous, lime segregated in thin filaments and threads; moderately alkaline.

The A horizon is silt loam or very fine sandy loam.

The B horizon has value of 4 or 5 dry and 3 or 4 moist. It is silt loam or silty clay loam.

Tencee series

The Tencee series consists of well-drained soils that formed in gravelly calcareous alluvium. They are shallow over indurated caliche. They are mainly on side slopes of pediments and the upper parts of the older alluvial fans at the base of limestone hills and escarpments. Slope is 0 to 10 percent. The mean annual precipitation is about 10 inches, and the mean annual air temperature is about 60 degrees F.

Tencee soils are similar to and near Lozier, Philder, and Nickel soils and are near Reakor, Reyab, and Tome soils. Lozier soils are underlain by bedrock at a depth of less than 20 inches. Philder and Reyab soils have a ustic-aridic moisture regime. Nickel and Reakor soils are deep and have a calcic horizon. Tome soils have a fine-silty control section.

Typical pedon of Tencee very gravelly sandy loam in an area of Reakor-Tome-Tencee association, gently sloping, about 50 feet east of the southwest corner of SE¼ NW¼, sec. 20, T. 21 S., R. 13 E.:

A1— 0 to 4 inches; light brownish gray (10YR 6/2) very gravelly sandy loam, brown (10YR 4/3) moist; weak fine and medium granular structure; slightly hard, very friable, nonsticky and nonplastic; common very fine roots; common fine interstitial pores; 45 percent gravel; strongly calcareous; moderately alkaline; clear wavy boundary.

C1ca— 4 to 15 inches; very pale brown (10YR 7/3) very gravelly sandy loam, pale brown (10YR 6/3) moist; part weak fine and medium granular structure, part massive; slightly hard, very friable, nonsticky and nonplastic; common very fine and few medium roots; common fine interstitial pores; 65 percent gravel; strongly calcareous; moderately alkaline; abrupt wavy boundary.

C2cam— 15 to 25 inches; white (10YR 8/1) carbonate-cemented material, very pale brown (10YR 7/3) moist; extremely hard; strongly calcareous; moderately alkaline; diffuse wavy boundary.

C3ca— 25 to 60 inches; white (10YR 8/1) extremely cobbly loam, very pale brown (10YR 7/3) moist; massive; soft, friable, slightly sticky and nonplastic; strongly calcareous; 85 percent carbonate-coated cobbles and fractured rounded petrocalcic fragments; moderately alkaline.

Gravel is carbonate coated limestone fragments and semirounded to angular petrocalcic fragments. Gravel content ranges from 35 to more than 80 percent, by volume. Depth to the petrocalcic horizon ranges from 6 to 20 inches.

The A horizon has hue of 7.5YR or 10YR, value of 5 to 7 dry and 3 to 5 moist, and chroma of 2 to 4. It is very gravelly sandy loam or very gravelly silt loam.

The C1ca horizon has value of 7 or 8 dry and 6 or 7 moist and chroma of 2 or 3. The C2cam horizon has hue of 7.5YR or 10YR and chroma of 1 to 3 moist. The C3ca horizon has value of 7 or 8 dry and chroma of 1 to 3. It is very cobbly loam or very gravelly loam.

Tome series

The Tome series consists of deep, well-drained soils that formed in mixed alluvium. They are on broad valley floors. Slope is 0 to 5 percent. Mean annual precipitation is about 9 inches, and the mean annual air temperature is about 61 degrees F.

Tome soils are similar to and near Largo, Prelo, and Mimbres soils. They are near Aztec, Alamogordo, Emot, Reakor, Tencee, Jal, Pintura, Doña Ana, Reeves, and Ogral soils. Mimbres soils have a cambic horizon. Largo soils have hue of 7.5YR or redder. Ogral soils have hue of 5YR. Aztec and Alamogordo soils have a gypsic horizon. Aztec, Emot, and Tencee soils contain more than 35 percent gravel in the control section. Reeves soils have a calcic horizon and a gypsic horizon. Prelo soils have a cambic horizon and have hue of 7.5YR or redder. Reakor and Jal soils have a calcic horizon. Pintura soils are sandy throughout. Doña Ana soils have an argillic horizon.

Typical pedon of Tome silt loam, 0 to 5 percent slopes, SW¼ SE¼ sec. 18, T. 23 S., R. 18 E.:

A11— 0 to 1 inch; pale brown (10YR 6/3) silt loam, dark grayish brown (10YR 4/2) moist; moderate medium platy structure; slightly hard, friable, slightly sticky and slightly plastic; few fine and very fine roots; few very fine tubular pores; strongly calcareous; moderately alkaline; abrupt smooth boundary.

A12— 1 inch to 5 inches; pale brown (10YR 6/3) silt loam, brown (10YR 4/3) moist; weak medium subangular blocky and very coarse granular structure; slightly hard, friable, pores; strongly calcareous moderately alkaline; gradual smooth boundary.

AC— 5 to 14 inches; pale brown (10YR 6/3) silt loam, brown (10YR 4/3) moist; massive; slightly hard, friable, slightly sticky and slightly plastic; few fine and very fine roots; common fine tubular pores; strongly calcareous; moderately alkaline; gradual smooth boundary.

C— 14 to 60 inches; pale brown (10YR 6/3) silt loam, brown (10YR 4/3) moist; massive; slightly hard, friable, slightly sticky and slightly plastic; few fine and very fine roots; common fine tubular pores; strongly calcareous; moderately alkaline.

The A horizon has hue of 10YR or 7.5YR, value of 5 or 6 dry and 4 or 5 moist, and chroma of 2 to 4. It is loam, silt loam, or very fine sandy loam. In some pedons there is a thin layer of C material present on the surface, normally less than 1 inch thick.

The AC horizon has value of 5 or 6 dry and 3 or 4 moist and chroma of 3 or 4. It is silt loam, loam, or very fine sandy loam and has less than 15 percent material coarser than very fine sand.

The C horizon has value of 5 to 7 dry and 4 or 5 moist and chroma of 3 or 4. It is very fine sandy loam, loam, silt loam, or light silty clay loam.

Soils mapped in the detailed area as Tome soils have hue of 7.5YR in some pedons, which is outside the range defined for the Tome series, but this difference does not affect the use and behavior of the soils.

Wink series

The Wink series consists of deep, well-drained soils that formed in calcareous eolian sediment. They are on upland pediments. Slope is 0 to 3 percent. Mean annual precipitation is about 8 inches, and the mean annual air temperature is about 63 degrees F.

Wink soils are similar to Armesa, Reeves, Jal, Bluepoint, and Pintura soils. They are near Bluepoint, Onite, Pintura, Berino, Holloman, and Doña Ana soils. Armesa, Reeves, and Jal soils are more than 18 percent clay in the fine earth fraction. Reeves soils have gypsic mineralogy, and Jal soils have carbonatic mineralogy. Bluepoint and Pintura soils do not have a calcic horizon. Onite soils have an argillic horizon and do not have a calcic horizon. Berino and Doña Ana soils are more than 18 percent clay in the control section and have an argillic horizon. Holloman soils are less than 20 inches thick over gypsum.

Typical pedon of Wink loamy fine sand in an area of Bluepoint-Onite-Wink association, nearly level, SW¼ NW¼, sec. 27, T. 26 S., R. 6 E.:

A11— 0 to 2 inches; light brown (7.5YR 6/4) loamy fine sand, dark brown (7.5YR 4/4) moist; single grain; loose dry and moist, nonsticky and nonplastic; slightly calcareous, lime disseminated; moderately alkaline; clear smooth boundary.

A12— 2 to 8 inches; light brown (7.5YR 6/4) sandy loam, brown (7.5YR 5/4) moist; weak medium and coarse granular structure; soft, very friable, nonsticky and nonplastic; slightly calcareous, lime disseminated; moderately alkaline; clear smooth boundary.

B2— 8 to 18 inches; brown (7.5YR 5/4) sandy loam, dark brown (7.5YR 4/4) moist; weak medium subangular blocky structure; slightly hard, very friable, nonsticky and nonplastic; slightly calcareous, lime disseminated; moderately alkaline; gradual wavy boundary.

C1ca— 18 to 25 inches; pink (7.5YR 7/4) sandy loam, brown (7.5YR 5/4) moist; weak coarse subangular blocky structure; soft, very friable, nonsticky and nonplastic; moderately calcareous, lime disseminated and in soft nodules and mycelia; moderately alkaline; gradual wavy boundary.

C2ca— 25 to 36 inches; pink (7.5YR 7/4) sandy loam, light brown (7.5YR 6/4) moist; massive; slightly hard, very friable, slightly sticky and nonplastic; strongly calcareous, lime disseminated and in soft nodules and mycelia; moderately alkaline; gradual wavy boundary.

C3— 36 to 60 inches; light brown (7.5YR 6/4) sandy loam, brown (7.5YR 5/4) moist; massive; soft, very friable, slightly sticky and nonplastic; moderately calcareous, lime disseminated; moderately alkaline.

The depth to the Cca horizon ranges from 15 to 25 inches in most pedons but is as much as 35 inches in some pedons. Calcium carbonate content is more than 15 percent.

The A horizon has value of 5 or 6 dry and 4 or 5 moist. It is loamy fine sand, sandy loam, or fine sandy loam. A few pedons have an overburden of 2 to 10 inches of fine sand.

The B horizon has value of 5 or 6 dry and 4 or 5 moist and chroma of 3 or 4. It is sandy loam or fine sandy loam.

The Cca horizon has value of 7 or 8 dry. The C3 horizon has value of 5 or 6 dry. Texture is generally sandy loam, but is fine sandy loam or very fine sandy loam in some pedons.

APPENDIX D

SEDIMENT-SOIL DESCRIPTIONS MCGREGOR RANGE

SEDIMENT-SOIL DESCRIPTION,
SITE 1, POTTERY SITE,
OLD MCGREGOR HOMESTEAD

CLASSIFICATION: Typic (?) Torriorthent.
LOCATION: 0.5 km south of Shorad Gate-Benton Well Blacktop, on Benton Well-Sulphur Tank Rd., 100 m north of old McGregor Ranch, 25 m west of Benton Well-Sulphur Tank Rd., on vertical east bank of stream (Sec. 22, TS, R9E, SE edge of Orogrande N quad).
LANDFORM: Distal toeslope of an alluvial fan-apron complex.
PARENT MATERIAL: Fine-grained calcareous alluvium.
SLOPE: <1%
ELEVATION: ~4,100 ft (1,249.7 m).
SURFACE CHARACTER: Sheetwash eroded, sparse creosote bush.
VEGETATION: Sparse desert scrub.
DESCRIBED BY: D. L. Johnson and D. N. Johnson, 6/9/96.
SAMPLED BY: D. L. Johnson and D. N. Johnson, 6/9/96.
EXPOSURE: Backhoe-dressed stream bank.

Soil/Geologic Unit	Depth (cm)	Description
AC/Unit 1	0-25	Brown/dark brown (7.5YR 4/4m, 5/4d) fine sandy loam unit that is surface wash-eroded, and destratified (pedogenicized) in upper part, stratified in lower; pottery sherds eroding out of surface from this unit in other nearby pedons.
2ACb/Unit 2	25-110	Brown/dark brown (7.5YR 4/4m, 5/4d) stratified sandy clay loam unit with four main substrata; weakly to moderately pedogenicized; land snails present.
3ACb/Unit 3	110-180	Brown/dark brown (7.5YR 4/4m, 5/4d) destratified fine sandy loam unit, with extremely abundant wasp/cicada structures (krotovina); moderately to strongly pedogenicized, with large scale joints and structures up to 15 cm across; unit has positive lateral side wall expression in naturally eroded and weathered side wall; varies in thickness from 70 cm where described to 40 cm 5-6 m to north; land snails present.
4AC/Unit 4	180-260	Brown/dark brown (7.5YR 4/4m, 5/4d) largely destratified clay loam unit; moderately pedogenicized, with reddish sand-infilled krotovina.

Remarks: All units are pedogenized, with Unit 3 more so than others. Land snails of the high spired dextral coiled *Physa virgata* kind occur in Units 2 and 3, in the latter they occur 10 cm below its upper boundary (snails identified by Prof. Art Metcalf, UTEP, El Paso). Pottery sherds present in some pedons of Unit 1.

The backhoe-dressed portion of this profile shows little of the strongly expressed strata, structure, and side wall profile that the adjacent, naturally exposed stream bank displays. In pits and trenches that are long-exposed to the elements, the subtleties and nuances of stratigraphy and soil evolution often are much better expressed. (See Table 10 for chemical and particle size data).

SEDIMENT-SOIL DESCRIPTION,
SITE 2, SULPHUR TANK

CLASSIFICATION: Typic Petrocalcids.
LOCATION: 5.6 miles (9 km) south of Shorad-Benton Well Blacktop and 50 m west of Benton Well- Sulphur Tank Rd., just north of Sulphur Tank (NW ¼, NW ¼, SW ¼, Sec. 15, T23N, R9E, Orogrande S quad).
LANDFORM: Relict alluvial fan.
PARENT MATERIAL: Very gravelly, limestone-derived alluvium.
SLOPE: 1-2%.
ELEVATION: ~4,225 feet (1,288 m).
SURFACE CHARACTER: Common badger and gopher mounds/burrows.
VEGETATION: Desert scrub (creosote bush, etc.).
SAMPLED BY: D. L. Johnson and D. N. Johnson, 6/4/96.
DESCRIBED BY: D. L. Johnson and D. N. Johnson, 6/4/96.
EXPOSURE: Backhoe 'T' trench.

Horizon	Depth (cm)	Description
A	0-10	Brown (7.5YR 5/4m, 6/4d) loamy sand; strong medium and coarse platy structures; nonsticky when wet, very friable when dry; strongly effervescent with dilute HC1; common medium and large roots; common and many medium and large pores along ped interfaces and as biochannels; abrupt smooth boundary.
Ak (C)	10-120	Brown (7.5YR 5/4m, 6/4d) very gravelly loamy sand; massive structure between lithic and rubbly caliche clasts (see photos); nonsticky when wet, friable when dry; strongly effervescent with dilute HC1; few medium and large roots in upper horizon, very few medium roots in lower; common fine and medium pores; abrupt wavy boundary.
$Bk1^{ob}$ (2Bkm1)[1]		Where present in this T-trench, the Bk1 horizon consists of whitish laminar but discontinuous (nonlayer-cemented) plates of indurated caliche (petrocalcic material) and occurs at about 30-50 cm depth (it has been obliterated in this described pedon). Where present it is the uppermost of the <u>in situ</u> formed caliche layers, and is separated from the underlying main Bkm (petrocalcic) horizon by thin partings. Both horizons have been essentially obliterated in this particular described pedon, but a preserved fragment of the Bk1 is present, having been displaced nearly a meter downward and tipped upside down owing to bioturbation (see Figure 112)..
Bkm^{ob} (2Bkm2)		The Bkm horizon, where present in this 'T' trench though disrupted and largely destroyed in this particular described pedon by bioturbation consists of white, indurated, lamellar and massive petrocalcic horizon (caliche) which formed in stratified and imbricated fan gravels. In those pedons where it is present it occurs between about 50-110 cm depth (see Figure 112).
Bk2	120-152	The Bk2 horizon, discontinuous in this pedon, consists largely of caliche-coated gravels that were originally stratified and imbricated. It is only intermittently present in this 'T' trench, having been completely destroyed in some pedons; where present it occurs between about 110-150 cm depth (see Figure 112). In this described pedon it is present as several residual 'islands' surrounded by extensively bioturbated Ak horizon material.
Ak	152-200+	The Ak horizon has expanded downward via wholesale bioturbation of this and adjacent pedons. The Ak horizon here is the same as, and contiguous with, the Ak horizon described above between 10-120 cm depth, except that roots are largely absent here.

[1] The superscript 'ob' on some horizon notations (e.g., $BK1^{ob}$) indicates that the horizon has been obliterated by bioturbation. The horizon notations set off in brackets are those normally assigned by NRCS (SCS) personnel in their soil descriptions that are based on a classificatory-genetic philosophy that is fundamentally different from that used in this.

<u>Remarks</u>: This and other pedons in the 'T' trench of site 2 demonstrate the efficacy of bioturbation, presumably mainly by badgers, in destratifying and deimbricating originally geogenic, water-deposited fan sediments of the Southwest. They also demonstrate the depth to which the process can occur on relict fan segments like this one. In fact, the backhoe pit provides visual evidence that in some places the Bk1, Bkm, and Bk2 horizons have been completely destroyed by bioturbation at the expense of a greatly vertically expanded Ak horizon (the biomantle). As a consequence, the biomantle here is extremely viable in thickness, ranging from 23 cm at its shallowest to beyond the bottom of the pit at 200+ cm. Based on 16 measurements from the backhoe pit walls, the biomantle here ranges in thickness from 23, 30, 33, 36, 36, 39, 41, 41, 51, 51, 53, 53, 120, 200, 200+, and 200+ cm.

The horizons of this (pedon 1) and two other pedons measured in the 'T' trench are:

horizon	*pedon 1**	*pedon 2***	*pedon 3****
A	0-10 cm	0-10 cm	0-8 cm
Ak	10-120 cm	10-32 cm	8-200+ cm
Bk1	(missing)	32-50 cm	(missing)
Bkm	(missing)	50-113 cm	(missing)
Bk2	120-152 cm	113-200+	(missing)
Ak	152-200+		

**east wall pedon; **east wall pedon; ***north wall pedon.*

SEDIMENT-SOIL DESCRIPTION,
SITE 3, SAND CANYON NORTH,
GRAPEVINE CANYON FAN

CLASSIFICATION: Typic Torrifluvents (?).
LOCATION: Flat-bottomed sandy barranca of Sand Creek North that defines the southern border of Ditch Camp (O. Lee's Thousand Acre Ranch) immediately E. of where road crosses barranca at very corner of Sec. 35 (SE ¼, SE ¼, SE ¼, SE ¼, Sec. 35, T19S, R10E, Pipeline Canyon quad).
PARENT MATERIAL: Several sandy alluvial units buried by a dune sheet that is buried by at least two mudflows.
SLOPE: ~2-3%
ELEVATION: ~4,390 (1,338 m).
SURFACE CHARACTER: Surface mainly buried by a very thick sand pile containing abundant fire-cracked rock and other cultural resources.
VEGETATION: Desert scrub, yucca, creosote bush, etc.
DESCRIBED BY: D. L. Johnson, D. N. Johnson, and S. A. Hall, 6/5/96.
EXPOSURE: South wall of Barranca of Sand Creek North.

Geologic/Soil Unit	Depth (cm)	Description
Unit 1:Mudflows	0-55	Upper 15 cm is a recent, possibly historic, still stratified mudflow showing little evidence of destratification; 15-55 cm is an older destratified mudflow with abundant rodent krotovina; abrupt smooth boundary.
Unit 2:Sand sheet	55-155	Massive, faintly to nonstratified sand; in places a dark sandy topsoil is present, and in places with abundant krotovina; cultural materials are present in upper and lower part of topsoil; abrupt smooth boundary.
Unit 3: Alluvial sand	155-385	Stratified alluvium, moderately pedogenicized with vertically oriented cicada burrows throughout; abrupt smooth boundary.
Unit 4:Alluvial sand	385-420	Pedogenicized, faintly stratified sand unit; abrupt smooth boundary.
Unit 5:Alluvial sands and soils	420-500+	Multiple alluvial units that are pedogenicized, uppermost one strongly.

Remarks: Five units are exposed in this south wall of probably historically cut Sand Creek (North) barranca. Units 1 and 2 are respectively mudflow deposits over an eolian sand sheet (note artifacts in upper part of sand sheet). The other units are alluvially recycles, originally eolian sands. Apparently this part of the Tularosa Basin experiences an eolian 'venture effect' whereby prevailing southwest winds are channeled east-northeast over the southern Sacramento Mountains (see Figures 16 and 18). This effect is particularly noticeable on the divide between Grapevine Canyon on the north and Culp Canyon on the south, where large sand piles have accumulated during the Holocene, and which probably was present during the late Pleistocene as well. As sands and sandy A horizons of soils in the basin west and southwest of the Jarillas are episodically destabilized, they ultimately accumulate here, and are blown up the divided into the Sacramento Mountains footslopes. During stormflow periods they are washed back down onto the alluvial fans and deposited as alluvium. The pedostratigraphy exposed in the Sand Canyon (North) barranca indicates that this process has happened repeatedly, probably many times during the uplift of the Sacramento Mountains and commensurate down-dropping of the Tularosa Basin. Such buried sand and mudflow sequences probably function as local aquifers and acquicludes in the subsurface of the piedmont fans along the eastern Basin, and could have produced perched watertables and springs.

SEDIMENT-SOIL DESCRIPTION,
SITE 4, ESCONDIDA SITE
GRAPEVINE CANYON FAN

CLASSIFICATION: Mimbres series, fine silty-mixed, thermic Typic Camborthids.
LOCATION: 3.4 miles (5.5 km) E of Hwy 54, near the center of the upper flootslope of Grapevine Canyon fan (GPS, 32°, 37', 38" N. lat., 105°, 56', 49" W long; SE ¼, SE ¼, SW ¼, NE ¼, Sec. 30, T19S, R10E, Deadman Canyon quad).
LANDFORM: Upper footslope/lower midslope of alluvial fan.
PARENT MATERIAL: Fine-grained calcareous alluvium and mudflow sediments.
SLOPE: ~1%.
ELEVATION: ~4,123 feet (1,257 m).
SURFACE CHARACTER: Very abundant surface aboriginal cultural resources, and intermittent, but in places abundant, fresh and old (wasted) gopher mounds.
VEGETATION: Sparse desert scrub (occasional creosote bush, but with intermittent bare vegetation-free areas).
SAMPLED BY: D. L. Johnson, D. N. Johnson, and S. A. Hall, 6/5/96.
DESCRIBED BY: D. L. Johnson, 6/23/96.
EXPOSURE: Shelby core, 2 in. diameter x 4 ft long, pulled with hydraulic Giddings rig from middle of road (track) that passes through site.

Horizon	Depth (cm)	Description
A	0-19	Dark yellowish brown (10YR 4/4m, 5/4d) silty clay loam; weak, small and medium subangular blocky structures; sticky when wet, plastic when moist, soft and slightly hard when dry; strong effervescence with dilute HC1; few medium roots and pores; clear smooth boundary.
Bwk	19-129+	Dark yellowish brown (10YR 4/4m, 6/4d) silty clay loam; weak small and medium subangular blocky structures; sticky when wet, plastic when moist, soft to hard when dry; very few faint $CaCO_3$ filaments in places, matrix strongly effervescent with dilute HC1; partly stratified in places; few line and medium roots and pores.

Remarks: The described core was pulled in the track that runs across this site, extruded into two metal trays, wrapped in plastic wrap, and transported back to Urbana-Champaign, Illinois, where it was described, then sampled for sediment analyses. Two more cores were likewise pulled, wrapped, and transported the University of Texas, Austin, for pollen analyses by Professor Stephen A. Hall (results indefinite and indeterminate; no apparent *Zea mays* pollen).

Erosion by both running water and wind are more efficacious in removing sediment and in keeping the abundant artifacts surface-exposed on the Escondida site than are the combined processes of occasional fan alluviation and rodent bioturbation (mounding) in burying them (i.e., erosion vector > bioturbation+alluviation vectors; see vector analysis in Introduction). Otherwise, the artifacts on the fan would be buried. The same holds true for numerous archeological sites and cultural materials that are surface exposed at Ditch Camp (Oliver Lee's excessively eroded Thousand Acre Farm) upslope and higher on this same fan. (See Table 4 for chemical and particle size data.)

SEDIMENT-SOIL DESCRIPTION, SITE 5, BASSETT LAKE PLAYA

CLASSIFICATION: Closest series, Verhalen, fine-smectitic thermic Haplotorrents.
LOCATION: Floor of Bassett Lake playa, Bassett Lake quad, Hat Ranch, Otero Mesa.
LANDFORM: Upland playa in limestone bedrock-pediment depression; P1 mapping unit.
PARENT MATERIAL: Lacustrine (playa) sediment.
SLOPE: 0%.
ELEVATION: ~5,180 ft (1578.9 m).
SURFACE CONDITION: Other than stock hoof disturbance, none apparent.
VEGETATION: Sparse grass and a few small desert shrubs.
SAMPLED BY: D. L. Johnson and K. Fischer.
DESCRIBED BY: D. L. Johnson, 6/23/96.
EXPOSURE: 2 in x 4.4 ft Giddings core.

Horizon	Depth (cm)	Description
A	0-22	Very dark grayish brown (10YR 3/2m, 4/2d) clay; moderate medium subangular blocky breaking to angular blocky structures; sticky when wet, hard when dry; slight to moderate effervescence with dilute HC1; common fine roots and pores; abrupt clear boundary.
Bw	22-88	Dark brown (10YR 3/3m, 4/3d) clay; moderate medium and coarse subangular blocky breaking to angular blocky structures; slightly sticky to sticky when wet, hard when dry; moderately to strongly effervescent with dilute HC1; few fine vertical roots and pores; clear smooth boundary.
Bwk	88-140+	Dark yellowish brown (10YR 4/4m, 5/4d) clay and clay loam; moderate medium and coarse subangular blocky breaking to angular blocky structures; sticky when wet hard when dry; very few fine $CACO_3$ filaments along root traces, matrix strongly effervescent with dilute HC1; few fine roots and pores.

Remarks: The core was placed in two hemispherical PVC sections in the field, wrapped in plastic wrap, and transported back to the lab for description. When unwrapped and opened, the core separated at about 22 cm depth, suggesting that the playa once may have been plowed to this depth (the darker A horizon color also stops at about this depth; Mr. Charlie Lee, proprietor of Hat Ranch, said it had never been plowed). No stratification is apparent int he core, suggesting that either the sediments were never stratified, or if stratification was once present it dispersed via normal pedogenic overprinting via shrink-swell, root growth, soil animals, etc. (See Table 19 for chemical and particle size data.)

SEDIMENT-SOIL DESCRIPTION,
SITE 6, BLM BORROW PIT

CLASSIFICATION: Pintura (?) Series, mixed, thermic Typic Torripsamments.
LOCATION: 0.3 km W of Hwy 54, between mile markers 44-45, 4.3 mi (6.9 km) N of Hwy 506 (NE ¼, NW ¼, NW ¼, Sec. 10, T20S, R9E, Tres Hermanos SE quad), BLM land.
LANDFORM: Coppice dune, over sand sheet, over another sand sheet. DSC/A1/P1 mapping unit.
PARENT MATERIAL: Dune sand.
SLOPE: ~1%.
ELEVATION: 4,030 ft (1,228 m).
SURFACE CHARACTER: Entire landscape is covered with coppice dunes.
VEGETATION: Coppice dunes are anchored mainly by mesquite, with Russian thistle (tumbleweed) a common associated shrub.
SAMPLED BY: D. L. Johnson and D. N. Johnson, 3/13/96.
DESCRIBED BY: D. L. Johnson, 6/13/96 and 6/23/96.
EXPOSURE: Sand borrow pit.

Horizon/Sediment	Depth (cm)	Description
Unit 1, A	0-80	Coppice dune, partly stratified though mainly destratified, with incipient soil. Dark grown (7.5YR 3/5m, 4.6/6d) loamy fine sand grading downward to fine sand; massive and single grain; nonsticky when wet, loose to very friable when dry; many fine, medium, and large roots and pores (roots up to 8 cm dia.); abrupt, smooth boundary.
Unit 2,		
2Akb (C1)	80-105	Destratified sand sheet with weakly developed paleosol. Yellowish red (5YR 4/6m, 5/6d) fine sand; massive, with few cicada burrow structures; nonsticky when wet, soft when dry; few filaments of $CaCO_3$, strongly effervescent with dilute HC1; few fine and medium roots; clear smooth boundary.
2Bkb (C2)	105-140	Yellowish red (5YR 4/6m, 5/6d) fine sand; massive, with abundant cicada burrow structures; nonsticky when wet, soft to slightly hard when dry; few filaments of $CaCO_3$, strongly effervescent with dilute HC1; few fine and medium roots; abrupt smooth boundary.
Unit 3		
3Akb (C3)	140-160	Sand sheet with strongly developed paleosol. Yellowish red (5YR 4/6m, 5/6d) loamy fine sand; massive; nonsticky when wet, slightly hard to hard when dry; matrix moderately effervescent with dilute HC1, few thin carbonate filaments and infillings along cracks, joints and root channels; clear smooth boundary.
3B1tkb (Btkb)	160-250	Yellowish red (5YR 4/6.5m, 5/6d) fine sandy loam grading downward to fine sand; weak to moderate coarse subangular blocky structures, and few and common cicada burrow structures; matrix moderately to strongly effervescent with weak HC1, thin $CaCO_3$ films and infillings in pores; few fine roots; common fine and medium pores.
3B2kb (Bkb1)	250-390	Yellowish red (5YR 4/6m, 5/6d) fine sand; massive to weak HC1, thin $CaCO_3$ films and infillings in pores; few fine roots; common fine and medium pores; smooth wavy boundary.
3B4kmb (Bkb2)	460+	Dense but nonlaminar whitish petrocalcic horizon (caliche); massive with abundant cicada burrow structures in the upper part; violently effervescent with dilute HC1.

Remarks: The described section was the thickest and deepest of all the cuts in the borrow pit (each of the three units described here are present throughout the borrow pit). The surface coppice mound is partly stratified but is mainly destratified. Unit 2 coincides with the beginning of the first buried soil, formed in a late Holocene dune sheet that appears not to have been coppiced. Unit 2 overlies Unit 3, in which a strongly developed second buried soil in which a petrocalcic horizon has formed.

Cicada burrow structures are few in the 2Akb horizon of Unit 2, and common in its 2Bkb horizon. The upper 3B1tkb horizon of the buried soil in Unit 3 exhibits few to common cicada burrow structures, whereas its B horizons have been almost completely cicada-burrowed, including the upper part of the petrocalcic horizon. The second lower clay bulge in the B horizon (3B3ktb) is interpreted as a beta horizon formed over a chemical discontinuity (petrocalcic horizon) that migrated downward when this buried soil was forming as a surface-exposed soil.

A slight amount of $CaCO_3$ has been leached from the coppice dune and precipitated as thin filaments in the 2Akb horizon of Unit 2. Likewise, some $CaCO_3$ from the Unit 2 soil, and possibly from the coppice dune, has leached down to Unit 3 and precipitated as thin filaments of caliche in the 3B2kb horizon.

Three C-14 dates were obtained from each of the three units, but obtained from datable materials in an exposure adjacent to the one described here (see Figures 41, 42, 44, and Table 1). One date was on well-preserved Russian thistle (*Salsola kali*), popularly known as tumbleweed, collected from a thin (2-cm thick) layer at the base of a more or less stratified coppice (less destratification had occurred in the dated coppice dune than the one described here). Russian thistle is an exotic Old World species imported into this continent sometime prior to this century. The date indicates that this particular coppice dune formed about 40 years ago, probably during the mid to late 1950s or early 1960s, and in the process buried the *Salsola* plants that were growing on the dune sheet soil of Unit 2. The date also indicates that the buried soil of Unit 2 was surface exposed until the late 1950s or early 1960s. The fact that the dated coppice dune was less destratified than the described coppice dune above suggests that it formed somewhat later.

A second date on soil organic carbon (SOM) extracted from the first buried soil of Unit 2 gave an age of 670 ± 90 ryBP (see Table 1). The date indicates that Unit 2 is clearly prehistoric and was deposited sometime in the late Holocene. A third date, determined from inorganic carbon ($CaCO_3$) taken from the upper 10 cm of the caliche in the 3B4mb horizon, gave an age of $11{,}710 \pm 110$ ryBP. Inasmuch as this is the very uppermost part of a thick caliche, it probably would have been the last precipitated before this soil was buried by Unit 2. (See Table 5 for chemical and particle size data.)

SEDIMENT-SOIL DESCRIPTION,
SITE 7, RAILROAD GYPSITE SOIL

CLASSIFICATION: Typic Haplogypsids.
LOCATION: RR light at Dunes siding, Hwy 54 mile marker 50, on east (W facing) wall of RR cut (NW ¼, NW ¼, NE ¼, Sec. 15, T19S, R9E, Deadman quad.
LANDFORM: Low longitudinal, parabolic-like wasted gypsite dune lobe.
PARENT MATERIAL: Dominantly earthy gypsum ($CaSO_4$), with some carbonate ($CaCO_3$).
SLOPE: ~1%.
ELEVATION: ~4.008 ft (1.222 m).
SURFACE CONDITION: Badger burrows, some gopher mounds and ant mounds, thin veneer of sand to the south; to the north is a low lying drainage way. Rough, alkali-efflorescent-like character, gypsum and small selenite crystals.
VEGETATION: Estimated 30-40% low scrub. 60-70% bare ground.
SAMPLED BY: D. L. Johnson and D. N. Johnson, 3/16/96.
DESCRIBED BY: D. L. Johnson and D. N. Johnson, 3/16/96.
EXPOSURE: Railroad cut, east side (west-facing).

Horizon	Depth(cm)	Description
A (By)	0-80+	White, earthy gypsite 'dunal' coarse sandy loam grading downward to fine sandy loam; massive to extremely weak medium platy structure; friable to 70 cm when dry, slightly hard to 80 cm and somewhat hard to hard below 80 cm when moist; strongly effervescent with dilute HC1; selenite crystals in lower part of profile; very few fine roots in upper 20 cm, one large root (1 cm) at 60-80 cm; profile appears as one continuous horizon.

Remarks: This landform was apparently once a dune, although it is difficult to find a modern analog for reference. It seems not to have been a gypsum dune like the white sands comminuted selenite dunes emanating from Lake Lucero, though one cannot rule this out entirely. It seems more like it was an eolian-entrained earthy precipitate derived from the floor of the Great Wall of China Playa, or one of several smaller playas (Cedar Lakes) on it northeastern periphery. Whatever, it is now wasted down into an earthy mass whose dune-map 16) in the Holloman-Reeves Association, though the profile where described does not exactly fit the descriptions of either of those two series (see Appendix B). (See Tables 6 and 7 for chemical and particle size data.)

ABBREVIATED SEDIMENT-SOIL DESCRIPTION,
SITE 10, SAND PLAYA

CLASSIFICATION: Typic Torriorthents.
LOCATION: ~50 m east of Benton Well-Sulphur Tank Rd. ~0.65 km SSE of Benton Well (SE ¼, NW ¼, Sec 15, T22, R9E).
LANDFORM: Temporary playa with associated quartzose lunette that grades into a due sheet-sand pile unit.
PARENT MATERIAL: Playa sediments over a buried dune sheet.
SLOPE: <1%.
VEGETATION: Desert scrub.
SAMPLED BY: D. L. Johnson and D. N. Johnson, 6/9/96.
DESCRIBED BY: D. L. Johnson and D. N. Johnson, 6/9/96.
EXPOSURE: Backhoe 'T' trench.

Horizon	Depth (cm)	Description
A	0-78	Recent, more or less unpedogenicized playa sediments.
2Ab	78-220+	Sand sheet.

Remarks: This temporary playa occupies the lower, but not lowest, toeslope of the fan complex that drains from the east into the Jarilla Bolson (the lowest part of the depression is several hundred meters west and is occupied by a dune train which has dammed drainage there and created Benton Playa; see Figure 15). Sand Playa has an associated quartzose lunette dune on its north-northeast periphery.

The profile here is very similar to that observed at Wilde Missile Dump and Wilde Playa (sites 13 and 14). A piece of fire-cracked rock was noted at 1.3 m depth here within the buried sand sheet in the east wall of the pit.

For what it is worth, five deer were observed here when the section was described on June 9, 1996.

ABBREVIATED SEDIMENT-SOIL DESCRIPTION, SITE 13, WILDE MISSILE DUMP

CLASSIFICATION: Typic Torriorthents.
LOCATION: ~0.5 km east-southeast of Wilde Well, on road to Otero Escarpment near missile dump ~1 km north of graveled airstrip (SE ¼, NE ¼, SE ¼, Sec 35, T21S, R9E).
LANDFORM: Mid-lower toeslope of alluvial fan emanating on Otero Escarpment.
PARENT MATERIAL: Toeslope alluvial sediments over sheet sand.
SLOPE: <1%.
ELEVATION: ~4.05 FT (1.236 m).
SURFACE CONDITION: Runon site that has received alluvium recently (i.e., historically).
VEGETATION: Desert scrub (mainly creosote bush).
SAMPLED BY: D. L. Johnson and D. N. Johnson, 6/9/96.
DESCRIBED BY: D. L. Johnson and D. N. Johnson, 6/9/96.
EXPOSURE: Backhoe 'T' trench.

Horizon	Depth (cm)	Description
A	0-82	Brownish-pinkish alluvial toeslope fine fraction sediments, slightly pedogenicized (almost identical to Wilde Playa (site 14) A horizon).
2Ab	82-200+	Buried, moderately pedogenicized reddish sheet sand.

Remarks: This site is in the Jarilla Bolson on the toeslope of the west-draining alluvial fan-apron that originates along the Otero Escarpment on the east side of the basin. The stratigraphy shows that the A horizon pinkish color derives from the Permian redbeds that outcrop along the escarpment. It also shows that sheet sand formerly migrated across this surface, presumably from the southwest, then became buried by toeslope fan sediments emanating from the eastern escarpment. The brownish-reddish eolian sand derived from eroded sandy soils upwind (southwest), and from reddish Permian sandstones along the Otero Escarpment that washed into the Bolson, which was then wind-winnowed. The buried sand sheet here, and the buried sand sheets of nearby Sand and Wilde playas, demonstrate how sand is permanently removed from the 'Tularosa Basin sand cycle' via burial by alluviation (see Axiom 9 in Introduction).

ABBREVIATED SEDIMENT-SOIL DESCRIPTION,
SITE 14, WILDE PLAYA

CLASSIFICATION: Typic Torriorthents.
LOCATION: 0.25 km south-southwest of Wilde Well, on west central side of Wilde Playa.
LANDFORM: Temporary playa.
PARENT MATERIAL: Playa sediments over sand sheet.
SLOPE: <1%.
ELEVATION: ~4.037 ft (1.230 m).
SURFACE CONDITION: No disturbance apparent.
VEGETATION: Grass, scattered desert scrub.
SAMPLED BY: D. L. Johnson and D. N. Johnson, 6/9/96.
DESCRIBED BY: D. L. Johnson and D. N. Johnson, 6/9/96.
EXPOSURE: Backhoe 'T' trench.

Horizon	Depth (cm)	Description
A (C1)	0-85	Playa sediments.
2Ab (2C2)	85-200+	Reddish due sheet (sheet sand).

Remarks: This temporary playa is a few tens of meters east of the depressional thalweg (lowest elevation) on the very lowest toeslope of the west-draining alluvial fan-apron that originates along the Otero Escarpment to the east of the Jarilla Bolson. The playa formed as a consequence of drainage blockage against the massive dune train that has clogged, and is slowly migrating north-northeast up the Jarilla Bolson. It is, thus, a temporary playa.

SEDIMENT-SOIL DESCRIPTION, SITE 15, CACTUS

CLASSIFICATION: Calcic Petrocalcids.
LOCATION: On NE intersection of road that heads due north from the Wilde Well-Lee Tank road, about halfway between Wilde Well and Lee Tank (NW ¼, SW ¼, SW ¼, SW ¼, Sec 20, T21s, R10E, Wilde Tank quad).
LANDFORM: Intermediate lower toeslope of alluvial fan.
PARENT MATERIAL: Calcareous silty and sandy alluvium.
SLOPE: 1-2%.
ELEVATION: ~4.123 ft. (1.257 m).
SURFACE CHARACTER: Abundant badger burrows and associated mounds that contain caliche-coated clasts and petrocalcic chunks.
VEGETATION: Desert scrubs, short grasses, and cactus.
SAMPLED BY: D. L. Johnson and D. N. Johnson, 6/9/96.
DESCRIBED BY: D. L. Johnson and D. N. Johnson, 6/9/96.
EXPOSURE: Backhoe 'T' trench.

Horizon	Depth (cm)	Description
A1	0-5	Dark brown (7.5YR 3.5/4m, 6/4d) gravelly loam; moderate to strong medium platy structures; nonsticky when wet, very friable when dry; strongly effervescent with dilute HC1; common and medium roots; many medium pores between structural units and as biochannels; abrupt wavy boundary.
A2	5-17	Dark brown (7.5YR, 3.5/4m, 6/4d) gravelly loam; moderate medium subangular blocky to weak medium vesicular structures; slightly sticky when wet, slightly hard to hard when dry; strongly effervescent with dilute HC1; infilled cicada-like burrows common; some rodent/rabbit-like fecal pellets present (bioturbation); few medium roots; a common medium pores; gradual wavy boundary.
Bk1	17-54	Brown and dark brown (7.5YR, 4/4m, 6/4d) gravelly (limestone pebbles, cobbles) loam; moderate medium subangular blocky and moderate medium and large vesicular structures; slightly sticky when wet, hard to very hard when dry; very few fine carbonate filaments, matrix strongly effervescent with dilute HC1; infilled cicada-like burrows common; some clusters of rodent/rabbit-like fecal pellets present (bioturbation); few fine and medium roots; common; medium and coarse pores between structural units and as biochannels; clear wavy boundary.
Bk2	54-90	Brown and dark brown (7.5YR, 4/4m, 6/4d) very gravelly (limestone cobbles, boulders) and fine sandy loam; moderate medium subangular blocky structures; nonsticky when wet, friable when dry; gravels not layer-cemented but are coated with carbonates as a loose, nodular caliche rubble, matrix strongly effervescent with dilute HC1; few very fine roots; few and common fine pores; abrupt smooth and slightly wavy boundary.
Bkm	90-110+	White laminar, massive, strongly cemented, coarse gravelly petrocalcic horizon; few fine roots.

Remarks: Even though the colors key out as brown and dark brown on the Munsell charts, there is a notable reddish-pinkish tint to the sediments in the A1, A2, and Bk1 horizons in this pit. The same pinkish tint typifies the fine fraction sediments in the immediate area and upslope (east) to the obvious place of origin of the pinkish color—the Permian bedrock outcrops near the Old Wright Place several km upslope of this site.

Badger-sized mounds on the surface around the pit indicate that the animals burrow down to the petrocalcic horizon, and occasionally into it (one badger did burrow into the petrocalcic horizon for chunks of it were present in his back spoil).

The platy A1 horizon reflects recent surface sheetwash deposition. The A2, Bk1, and Bk2 horizons are strongly bioturbated by insects, yet horizon differentiation is still more or less displayed. The rubbleized or nodular caliche zone

defined by the Bk2 horizon exhibits zones where some pebbles are horizontally oriented, indicating that stratification is partly preserved, but in other places the stones are tipped randomly, indicating that the Bk2 horizon is partly mixed by bioturbation.

Cicada-like burrows are subtle but abundant in the A2 and Bk horizons. Clusters of rodent/rabbit-like fecal pellets occur in the A2 and Bk1 horizons and indicate bioturbation (burrowing).

The top of the petrocalcic (Bkm) horizon appears to be breaking up, possibly via recurrent badger burrowing from above; few fine roots penetrate these massive, intermittently ruptured, caliche-cemented platy zones. (See Table 8 for chemical and particle size data.)

SEDIMENT-SOIL DESCRIPTION,
SITE 16, PERMIAN-SANDSTONE LIMESTONE SITE

CLASSIFICATION: Typic Haplocambids.
LOCATION: About 2 km north of site 15 and intersection of N-S road that intersects the Wilde Well-Lee Tank road (W ½, NW ¼, SW ¼, Sec. 17, T21N, R10E, Wilde Tank quad).
LANDFORM: Toeslope of alluvial fan.
PARENT MATERIAL: Alluvium derived from Permian limestone and sandstone.
SLOPE: ~1%.
ELEVATION: ~4,100 ft (1,250 m).
SURFACE CHARACTER: Abundant gopher and badger burrows and mounds.
VEGETATION: Desert scrub (creosote bush, etc.), grasses, cactus.
SAMPLED BY: D. L. Johnson and D. N. Johnson, 6/9/96.
DESCRIBED BY: D. L. Johnson and D. N. Johnson, 6/9/96.
EXPOSURE: Backhoe 'T' trench.

Horizon	Depth (cm)	Description
A1	0-4	Dark brown (7.5YR 4/2m, 5.5/4d) slightly gravelly loam; moderate medium coarse platy structures; slightly sticky when wet, very friable when dry; strongly effervescent with dilute HC1; many medium roots; many medium pores along biochannels and on ped faces; abrupt wavy boundary.
A2 (AB)	4-24	Dark brown (7.5YR 3.5/4m, 6/4d) slightly gravelly loam; weak medium subangular blocky and moderate to strong medium vesicular (insect induced?) structures; slightly sticky when wet, slightly hard to hard when dry; matrix strongly effervescent with dilute HC1; many medium roots; many coarse pores; gradual wavy boundary.
Bt	24-74	Dark brown (7.5YR 4/4m, 5.5/4d) slightly gravelly clay loam; moderate medium subangular blocky to very weak medium vesicular structures; slightly sticky when wet, hard when dry; matrix very strongly effervescent with dilute HC1; common medium and fine roots and pores; gradual clear boundary.
Bw	74-138	Dark brown (7.5YR 4/4m, 6/4d) slightly gravelly silt loam; weak coarse subangular blocky structures; nonsticky when wet, slightly hard when dry; matrix strongly effervescent with dilute HC1; few and fine and medium roots and pores; abrupt smooth boundary.
2Ab	138-172	Reddish brown (5YR 4/4m, 5/4d) gravelly loamy fine sand; massive structure; nonsticky when wet, very friable when dry; matrix strongly effervescent with dilute HC1; very few fine root; common fine pores; gradual clear boundary.
2Bkb (2Bb1)	172-198	Reddish brown (5YR 3.5/4m, 5/4d) gravelly loamy fine sand; massive structure; nonsticky when wet, very friable when dry; matrix strongly effervescent with dilute HC1; very few fine roots and pores; abrupt wavy boundary.
2Bkmb (2Bb2)	198-210+	White gravelly, dense petrocalcic horizon containing common reticulate small biochannel-like pores.

Remarks: The gravelly components of the soil horizons on this fan toeslope are made up of both redbed sandstone and grayish limestones derived from Permian rocks along the Otero Escarpment. The reddish sandstone clasts are friable and incompetent, easily breaking down into reddish sand, and proving that some of the extensive reddish sand piles that clog the Jarilla Depression are from the Otero Escarpment, at least in this part of the Bolson.

The presence of 138 cm of relatively fresh sediment that buries a well-developed soil defined by the 2Ab, 2Bkb, and 2Bkmb horizons is evidence that this alluvial fan has been energy reactivated in the Holocene, probably Holocene, possibly protohistoric or historic. Reactivation probably was linked to vertical movements along the faults to the east,

with the Bolson being downdropped and the Sacramento Mountains/Otero Mesa upthrown. The fault scarp lineation is clearly evident on airphotos of the east side of this part of the Jarilla Bolson. Profile was sampled to 198 cm depth. (See Table 9 for chemical and particle size data.)

SEDIMENT-SOIL DESCRIPTION, SITE 37, GYPSUM PLAYA

CLASSIFICATION: Cacic Argigypsids.
LOCATION: On playa floor on N side of Desert-to-South Well road (SE ¼, SE ¼, NW ¼, Sec. 19, T24S, R8E, Desert quad).
LANDFORM: Playa lake bed.
PARENT MATERIAL: Gypsiferous playa sediments.
SLOPE: 0%.
ELEVATION: 4,064 ft (1,239 m).
SURFACE CHARACTER: Termite mud sheaths on playa vegetation.
VEGETATION: Sparse desert scrub (creosote bush), grasses; playa surrounded by coppice dunes anchored by mesquite.
SAMPLED BY: D. L. Johnson and D. N. Johnson, 6/14/96.
DESCRIBED BY: D. L. Johnson and D. N. Johnson, 6/14/96.
EXPOSURE: Backhoe 'T' trench.

Horizon	Depth (cm)	Description
A	0-32	Brown (7.5YR 4.5/4m, 6/4d) silty clay loam; strong very coarse platy structures, in places vesicular; nonsticky and very plastic when wet, very hard when dry; few and common calcareous and gypsiferous filaments, films and granules; strongly effervescent with dilute HC1; few fine and medium roots; many medium and coarse pores between structural units; abrupt wavy boundary.
Bky	32-75	Brown (7.5YR 5/4m, 6/4d) silt loam; massive grading to moderate and strong medium and coarse angular blocky structures, in places vesicular; slightly sticky and plastic when wet, extremely hard when dry; common small selenite (gypsum) books along small vertical biochannels, and many tiny rosettes; common finely disseminated caliche blebs and associated gypsum filaments and veinlets, matrix strongly effervescent with dilute HC1; few and common small (1-9 mm dia.) irregularly shaped termite biochannels with dark organic infillings and termite pellets; no visible roots; few coarse pores that appear to be termite biochannels; gradual diffuse boundary.
Cky (2Btky)	75-220	Brown (7.5YR 4/4m, 6/4d)clay; strong course angular blocky structures; sticky and very plastic when wet, extremely hard when dry; powdery caliche nodules concentrated in selenite enriched zones, matrix strongly effervescent with dilute HC1; large (several dm^2) pedoslickensides begin at 190 cm through 220 cm depth.
2ACby (3Byb)	220+	Possible buried soil begins at 220 cm depth.

Remarks: In the C horizon between 110-170 cm depth, selenite has precipitated into books 25 cm across and up to 2 cm thick. Gypsum may be washing in as airfall gypsiferous dust, leaching downward to the water table, then wicking up into the playa sediments (the bottom of the pit was moist). The B horizon has abundant vertical filaments and veinlets of caliche and gypsum that extend from the bottom of the A to the upper C horizon.

Fire-cracked rock is abundant on old shorelines of this playa, but whether the sites are chronologically related to the strandlines is unclear. Sediment samples for pollen analyses were collected for Professor Stephen Hall, University of Texas, Austin.

This gypsum enriched playa may be the southernmost of the gypsum playas, which are common farther north, especially on the west, north, and east sides of the Jarilla Mountains (e.g., Salt Cedar Playa, Cox Well Playa, Lone Butte Playa, Great Wall of China Playa, etc.). Vertisol Playa, however, has gypsum precipitates (selenite). (See Table 12 for chemical and particle size data.)

SEDIMENT SOIL DESCRIPTION
SITE 38, VERTISOL PLAYA

CLASSIFICATION: (Series?); very fine chromic Haplotorrerts.
LOCATION: On playa floor, about 2.7 miles (4.3 km) SW of Desert, immediately E of RR tracks (32°) 10' 16-20" N, 106° 12' 9-12" W (SW ¼, NE ¼, NW ¼, SW ¼, Sec 35, T24S, R7E, Desert quad).
LANDFORM: Playa.
PARENT MATERIAL: Smectite-rich playa sediments.
SLOPE: 0%.
ELEVATION: 4.041 ft (1.232 m).
SURFACE CHARACTER: Strongly, deeply, and extensively cracked with a granulated surface soil mulch; badger mounds and burrows common above lowest (6 ft) high water bench; many small shallow burrows of unknown origin present on playa floor.
VEGETATION: Episodically present herbaceous plants (when playa is wet).
SAMPLED BY: D. L. Johnson and D. N. Johnson, 6/14//96.
DESCRIBED BY: D. L. Johnson and D. N. Johnson, 6/14/96.
EXPOSURE: Backhoe 'T' trench.

Horizon	Depth (cm)	Description
A1 (A)	0-10	Dark brown (10YR 3.5/3m, 4/3d) clay; moderate medium granular and moderate medium and coarse sphenoidal (wedge-shaped) structures; slightly surface mulched with loose soil granules; slightly sticky when wet, hard when dry; strongly effervescent with dilute HC1; some pedoslickensides common and many fine pores; many fine and medium roots; clear smooth boundary.
A2 (Bss)	10-85	Dark brown (10YR, 4/3.5m, 5/3d) clay; strong coarse sphenoidal (wedge-shaped) cross cutting structures; plastic when wet, hard when dry; occasional small caliche blebs, strongly effervescent with dilute HC1; many pedoclickensides along surfaces of sphenoidal structures; when dry, common cracks between wedge-shaped structural units, and as vertical cracks from surface to >2 m depth, few small black pebbles (5-8 mm dia.); gradual diffuse boundary.
Ck (Bssk)	85-270+	Dark brown (10YR, 4/3.5m, 5/3d) clay; strong coarse sphenoidal (wedge-shaped) cross cutting structures; plastic when wet, very hard when dry; occasional small whitish caliche blebs, strongly effervescent with dilute HC1; slickensides throughout as in A2 horizon; when dry, common cracks between wedge-shaped structural units, and as vertical cracks from surface to >2 m depth; adult Planorbid snail shell at 150 cm depth; few small black pebbles 5-8 mm dia., one 18 mm dia. at 160 cm depth; gradual diffuse boundary.

Remarks: The shells of two special of snails are present on this playa, the flattish, broad coiled *Planorbella tenuis*, an aquatic snail, and the high spired dextral coiled land snail Physa *virgate*. No live forms of either species were observed. The land snail presumably still lives in the area, and assuming so probably estivates during dry periods and becomes active during wet periods. The aquatic snail may either live in an estivated state in the playa sediments during dry periods and revive periodically when the playa floods, or it may episodically recolonize the playa when it floods.

A radiocarbon determination on multiple randomly collected adult Planorbid shells from the playa floor indicates that the last 'Planorbid event,' and a time of significant flooding, was after 1945, for the shells contained relatively modern, post-1945 bomb ^{14}C. Planorbid snails are common on the playa floor to a bench about 6 ft (1.8 m) above it. No Planorbid snails were observed above this bench, but higher strandlines are apparent along the northern side of the playa. Gypsum (selenite) occurs along the entrance road to the playa at about 4,070 ft elevation (highest standline?).

Fire-cracked rock, occasional potsherds, and evidence of wasted hearths are present at various levels along the northern side of the playa, and may or may not be associated with the higher strandlines there. The playa floor itself has pottery and fire-cracked rock scattered about here and there, all of which have been disturbed and moved laterally, at least, by argillitubation of the playa sediments as they swell when wetted and shrink upon drying. The presence of these artifacts on the surface indicates that either they are young enough not to have been incorporated into the upper part of the vertisol

by falling into cracks, or that they do fall in and are being recycled vertically in the upper vertisol and as a consequence periodically reappear at the surface (for details on the disturbance effect of argilliturbation on cultural resources see Johnson and Hester 1972; Wood and Johnson 1978).

When described this vertisol showed evidence of cracking to 180 cm depth where width of cracking at the surface was up to 14 cm. The cracking pattern defines surface polygons, most of which fell between 110-160 cm in width and occasionally to 210 cm. Cracks infilled with organic debris and mulched (granulated) soil probably form annually upon drying after summer rains, but appear not to reform in previous cracks (cracking pattern is different each season as suggested by grass-infilled former cracks).

The backhoe pit was described and sampled on June 14, 1996, but when revisited on July 27, 1996, it was completely filled with runoff water from recent rains. At this time abundant, though patchy, herbaceous vegetation had sprouted here and there on the playa floor, and a small 10-30 cm wide meandering erosional channel had been cut on the east side of the pit into it (see Figure 76). A rattlesnake was observed on the 6-ft bench on the south side of the playa and 18 oryx (15 adult, 3 juveniles) were surprised while they were feeding on the playa floor on this date.

Samples from this pit were collected for pollen analyses on June 6 by Professor Stephen Hall, University of Texas, Austin. In e-mail correspondence dated June 19, Hall had this to say about the pollen analysis:

> The basal sample contains lots of pollen, moderately (well) preserved, with many charred particles but without the fluffy organic debris of Lake Tank Playa. The pollen is suitable for scientific study, but I wonder about the integrity of the vertisol environment. One way to test its integrity is to AMS date several zones to see what the ^{14}C age variation might be.

(See Table 11 for chemical and particle size data.)

SEDIMENT SOIL DESCRIPTION,
SITE 39, ALVARADO TANK NO. 2

CLASSIFICATION: Tome Series, Fine-silty, mixed, thermic Typic Torriortherts.
LOCATION: Site is ±60 m south of Alvarado Tank No. 2 (N ½, SW ½, SE ¼, Sec. 34, T24S, R8E).
LANDFORM: Alluvial fan ultra-toeslope quad flats (almost a playa).
PARENT MATERIAL: Fine-grained alluvium derived from limestone that buries sheet dune sand that itself buries silty playa-like deposits.
SLOPE: <1%.
ELEVATION: ~4.099 ft (1.249 m).
SURFACE CHARACTER: Occasional small mammal burrows and mounds.
VEGETATION: Desert scrub, mainly creosote bush.
SAMPLED BY: D. L. Johnson and D. N. Johnson, 6/12/96.
DESCRIBED BY: D. L. Johnson and D. N. Johnson, 6/12/96.
EXPOSURE: Backhoe 'T' trench.

Horizon	Depth (cm)	Description
A	0-8	Dark brown (7.5YR, 3/4m, 6/4d) silt; nonsticky when wet, friable when dry; strongly effervescent with dilute HC1; many medium coarse roots and pores; abrupt smooth boundary.
A2	8-50	Dark brown (9YR, 3/3m, 6/4d) silt loam; slightly vesicular within strong, coarse subangular blocky structures; nonsticky when wet, slightly hard when dry; strongly effervescent with dilute HC1; few fine roots; common fine pores; clear wavy boundary.
Bw	50-110	Dark brown (7.5YR, 3/4m, 6/4d) silt loam; massive structure; non-sticky when wet, friable when dry; strongly effervescent with dilute HC1; very few fine roots; common fine pores; gradual smooth boundary.
2Ab	110-155	Brown (7.5YR, 4/4m, 6/4d) sand; almost loose, grading to massive structure; nonsticky when wet, friable when dry; strongly effervescent with dilute HC1; very few fine roots; few fine pores; abrupt clear boundary.
3ABb	155-210+	Brown (9YR, 4/3.5m, 6/3d) silt loam; moderate medium prismatic structures; slightly sticky when wet, hard when dry; strongly effervescent with dilute HC1; no roots; common fine pores.

Remarks: This more or less playa occupies a distal toeslope of an alluvial fan complex that heads to the north and east. The 2Ab (110-155 cm) and 3ABb (155-210+) horizons are weakly expressed buried soils, the first formed in dune sheet sand, the second in silty playa-like materials. The stratigraphy here suggest that at least some of the distal toeslope playas in this part of the Tularosa Basin are ephemeral (short-lived), and that valley dynamics include episodic faulting (down-dropping) of the Tularosa graben, episodic dune sand migrations, and possibly climatic change and/or episodic megastorms.

SEDIMENT-SOIL DESCRIPTION,
SITE 40, DUST PIT

CLASSIFICATION: Calcic Petrocalcids.
LOCATION: 1.1 miles (1.8 km) NE of Borrego Tank, 50 ft E of dirt road that passes over Borrego Ridge road, at the intersection of SE corner Section 25 and NE corner Sec. 36, T24S, R8E, Desert NE quad.
LANDFORM: Upper midslope of slightly dissected colluvial-alluvial fan, A2-A3 mapping surface.
PARENT MATERIAL: Calcareous gravelly alluvium shed from limestone bedrock ridge upslope.
SLOPE: 2-3%.
ELEVATION: ~4.195 ft (1.279 m).
SURFACE CHARACTER: Abundant badger and rodent burrows and mounds.
VEGETATION: Desert scrub (creosote bush mainly).
SAMPLED BY: D. L. Johnson and D. N. Johnson, 6/5/96.
DESCRIBED BY: D. L. Johnson and D. N. Johnson, 6/5/96.
EXPOSURE: Backhoe 'T' trench.

Horizon	Depth (cm)	Description
A	0-5	Dark yellowish brown (10YR, 4/3.5m, 6/3.5d) very fine sandy loam; moderate medium platy structures; nonsticky when wet, very friable when dry; strongly effervescent with dilute HC1; appears nonbioturbated; common fine and medium roots; many medium and large pores; abrupt smooth boundary.
Ak1 (A/B)	5-37	Dark yellowish brown (10YR 4/3.5m, 6/3.5d) gravelly very fine sandy loam; semivesicular to massive and weak medium subangular blocky structures; very slightly sticky when wet, very friable when dry; some nodular caliche and caliche-coated clasts, matrix strongly effervescent with dilute HC1; some old and recent rodent-sized krotovina, several containing nodular caliche and caliche-coated gravels and rodent droppings; common fine and medium roots; common medium pores; gradual wavy boundary.
Ak2 (Bk)	37-70	Dark yellowish brown (10YR 4/3.5m, 6/3d) gravelly very fine sandy loam grading downward to sandy loam; massive and very weak medium subangular blocky structures; very slightly sticky when wet, very friable when dry; some nodular caliche and gravels with caliche coats, matrix very strongly effervescent with dilute HC1; some old and young rodent-sized krotovina, several containing nodular caliche and caliche-coated gravels and rodent-like pellets; few fine and medium roots; common medium pores; abrupt wavy boundary.
Bkm1	70-102	White, sandy loam, dense, massive caliche (petrocalcic horizon) that cements weakly stratified gravels capped by thin (≤ 10 cm) very dense lamellar caliche; several old badger-sized (≤ 20 cm dia.) and rodent-sized krotovina; matrix violently effervescent with dilute HC1; few fine roots and occasional medium roots, mainly in krotovina; abrupt wavy boundary.
Bkm2	102-190	Nonlaminar dense caliche cementing weakly stratified gravels; this horizon surface area in pit is about 2% visible krotovina (some ≤ 35 cm in diameter, most smaller); matrix violently effervescent with dilute HC1; very few fine and medium roots and pores in krotovina.

Remarks: The platy and thin A horizon with its lower abrupt boundary is recent (last few years) surface wash. The Ak1 and Ak2 horizons are destratified, with abundant evidence of bioturbation, containing new and old krotovina and burrow fillings, and with caliche rubble brought up biomechanically into these horizons from the Bk horizons. Fecal pellets are present in some krotovina, but also occur sporadically in the Ak1 and Ak2 horizons, suggesting the presence of former krotovina now no longer visible.

Some ovate kangaroo rat[2] fecal pellets, 2-3 mm in diameter and composed of organic silt, were collected from the base of the Ak2 horizon (60-70 cm depth) and were submitted for ^{14}C analysis. Both the organic and inorganic ($CaCO_3$) carbon fractions were dated, respectively, yielding ages of 1,080±110 and 9,200±70 radiocarbon years before present (see Table 1 and Appendix A). The disparity in the ages, specifically the much older inorganic carbon date, is presumably attributed to dead radiocarbon contamination of the inorganic ($CaCO_3$) carbon fraction. Presumably the dead carbon came from the Permian limestone rocks that form the parent material for the soils along the fan-apron. Nevertheless, the organic carbon date shows that: (1) organic materials like fecal pellets are preserved in some McGregor sediments and can be dated; (2) kangaroo rats had a nest here a thousand years ago; and (3) the krotovina in which the dung was presumably deposited is either not discernible or it no longer exists and has been destroyed by subsequent bioturbation.

The destratified biomantle, from the surface to the top of the Bk1m horizon, is variable in depth, ranging from 64 to 76 cm as determined by measurements of 64, 69, 69, 70, 70, 71, 71, 71, 72, 74, 74, and 76 cm from 13 pedons in site 40 'T' trench. Gravels in the Bkm1 and Bkm2 horizons are stratified (unbioturbated).

The horizons of this and two other pedons measured in the 'T' trench of this site are:

horizon	*pedon 1*	*pedon 2*	*pedon 3*
A	0-5 cm	0-5 cm	0-6 cm
Ak1	5-37 cm	5-37 cm	6-45 cm
Ak2	37-70 cm	37-70 cm	45-72 cm
Bkm1	70-102 cm	70-98 cm	72-96 cm
Bkm2	102-190+ cm	98-190+ cm	96-190+ cm

(See Table 17 for chemical and particle size data.)

[2] Identified by Walt Whitman, NMSU mammalogist and kangaroo rat specialist (personal communication 1996).

SEDIMENT-SOIL DESCRIPTION, SITE 41A, TWIN PITS

CLASSIFICATION: Typic Calciorthids.
LOCATION: 65 ft (20 m) W of NW intersection of Borrego Ridge and South Well roads (see location on Geomorphic Map, Desert NE quad, Vol. II of this report).
LANDFORM: Alluvial fan; A1 mapping unit.
PARENT MATERIAL: Gravelly, limestone-derived alluvium.
SLOPE: 1-2%.
ELEVATION: ~4.388 (1.337 m).
SURFACE CONDITION: Common badger and gopher mounds and burrows.
VEGETATION: Desert scrub (creosote bush dominantly).
SAMPLED BY: D. L. Johnson and D. N. Johnson, 6/4/96.
DESCRIBED BY: D. L. Johnson and D. N. Johnson, 6/4/96.
EXPOSURE: Backhoe 'T' trench.

Horizon	Depth (cm)	Description
A1	0-8	Dark brown (10YR 3/3.5m, 5/3d) slightly gravelly loam; moderate medium vesicular to very weak coarse platy structures; slightly sticky when wet, friable when dry; strongly effervescent with dilute HC1; many medium roots and pores; abrupt smooth boundary.
A2 (Bt1)	8-40	Dark brown (10YR 3/3.5m, 5/3d) slightly gravelly loam grading downward to sandy clay loam; weak very coarse prismatic structures; sticky when moist, hard when dry; strongly effervescent with dilute HC1; many fine and medium roots and pores; gradual wavy boundary.
Bk1 (Bt2)	40-68	Dark yellowish brown (10YR 4/4m, 5.5d) slightly gravelly sandy clay loam; very massive to weak subangular blocky structures; slightly sticky when wet, slightly hard to hard when dry; common and powdery $CaCO_3$, strongly effervescent with dilute HC1; few fine and medium roots and pores; gradual irregular boundary.
Bk2 (Btk1)	68-142	Light yellowish brown (10YR 6/4m, 6.5/3d) gravelly very fine sandy loam grading downward to sandy clay loam; massive to weak medium angular blocky structures; slightly sticky when wet, friable to slightly hard when dry; common and powdery $CaCO_3$, strongly effervescent with dilute HC1; few fine and medium roots and pores; very gradual smooth boundary.
Bk3 (Btk2)	142-200+	Brown (7.5YR 5/4m, 6/4d) slightly gravelly sandy clay loam; massive; slightly sticky when moist, slightly hard to hard when dry; abundant and powdery $CaCO_3$, strongly effervescent with dilute HC1.

Remarks: T-trench is devoid of laminar caliche except in one 40-cm-wide area at the top of the Bk1 horizon. Otherwise, the interface of the upper part of the BCk1 horizon is nodular, and the lower part massive. Common signatures of bioturbation include abundant small krotovina, nodular calichefied clast tipped at all angles, and occasional cylindrical krotovina tipped randomly through A2, Bk1, and Bk2 horizons. Some cylindrical, vertical biochannels are present in the upper Bk2 horizon. From 142 cm down, the profile is highly calichefied within reddish powdery fine fractions.

The polypedon of which this soil is a member is slightly lower lying in elevation (< 1 m) than the adjacent slightly higher lying polypedon of site 41B. This lower lying surface is a reactivated fan that appears to be episodically accreted with fine fraction (mainly).

The biomantle, from the surface to the top of the Bk1 horizon, is variable in depth, ranging from 30 to 53 cm (measurements of 40, 30, 43, 36, 38, 53, 46, 43, 36, 36, and 43 cm from 11 pedons in site 41A 'T' trench).

The horizons of this and two other pedons measured in the 'T' trench are:

horizon	*pedon 1*	*pedon 2*	*pedon 3*
A	0-8 cm	0-9 cm	0-6 cm
A2	8-40 cm	9-39 cm	6-36 cm
Bk1	40-68 cm	38-66 cm	36-71 cm
Bk2	68-142 cm	66-142 cm	71-145 cm
Bk3	142-200 cm	142-200 cm	145-200 cm

(See Table 18 for chemical and particle size data.)

SEDIMENT-SOIL DESCRIPTION,
SITE 41B, TWIN PITS

CLASSIFICATION: Typic-Calcic Petrocalcids.
LOCATION: ~100 ft (30 m W of NW intersection of Borrego Ridge and South Well roads (see location on Desert NE quad, Vol. II of this report).
LANDFORM: Alluvial fan; A2 mapping unit on Desert NE quad, Vol. II of this report.
PARENT MATERIAL: Gravelly limestone-derived alluvium.
SLOPE: 1-2%.
ELEVATION: ~4.390 (1.338 m).
SURFACE CONDITION: Common badger and gopher mounds and burrows.
VEGETATION: Desert scrub (creosote bush dominantly).
SAMPLED BY: D. L. Johnson and D. N. Johnson, 6/4/96.
DESCRIBED BY: D. L. Johnson and D. N. Johnson, 6/4/96.
EXPOSURE: Backhoe 'T' trench.

Horizon	Depth (cm)	Description
A1	0-5	Dark yellowish brown (10YR 3/4 m, 6/3.5d) gravelly very fine sandy loam; moderate medium platy structures; very slightly sticky when wet, very friable when dry; strongly effervescent with dilute HC1; common fine and medium roots; many medium vesicular-like pores; abrupt smooth boundary.
A2 (Bw)	5-34	Dark yellowish brown (10YR 3.5/4m, 6/3.5d) gravelly very fine sandy loam; vesicular and moderate subangular blocky structures; very slightly sticky when wet, very friable when dry; common fine and medium roots; many medium pores; abrupt wavy boundary.
Ak (Bk)	34-50	Dark yellowish brown (10YR 3.5/4m, 6/3.5m) very gravelly fine sandy loam; weak medium subangular blocky structures; slightly sticky when wet, very friable when dry; matrix strongly effervescent in dilute HC1, caliche-coated clasts common; small fecal pellets in many krotovina in horizon; few fine medium roots; many medium pores; abrupt wavy boundary.
Bkm	50-110	White lamellar (petrocalcic) very gravelly coarse sandy loam caliche 8-10 cm thick, with subjacent multiple lamellar caliche layers 3-8 cm thick (much whiter than lower horizon, gravels stratified and imbricated); matrix strongly effervescent in dilute HC1; very few fine roots and interclast pores; abrupt wavy boundary.
2ABkb (2Bkb)	110-180+	White caliche coated gravels, with coatings mainly on clast undersides; gravels relatively unstratified and unimbricated (i.e., destratified); matrix highly effervescent in dilute HC1; very few fine roots, many interclast pores.

Remarks: The pedons in this backhoe pit are strongly bioturbated in places, presumable by badgers whose ability to burrow in gravelly sediments is legend. In places the Ak, Bkm, and 2ABkb horizons are obliterated. One giant krotovina that measured 64 cm in diameter occurs at the top of the Bkm horizon and narrows to 41 cm at 112 cm depth in the 2Akb horizon. Other krotovina are ≥ 15 cm in diameter and occur within the Bkm horizon.

The polypedon of which this soil is a member is slightly higher lying in relief (≤ m) than the adjacent slightly lower lying polypedon of site 41A. This slightly higher lying surface is one of several relict islands of A2 alluvium in this broad draw.

The biomantle, from the surface to the top of the Bkm horizon, is variable in depth, ranging from 33 to 112 cm (measurements of 34, 43, 54, 46, 51, 36, 41, 33, 41, 112, and 48 cm from 11 pedons in site 41B 'T' trench).

The horizons of this and two other pedons measured in the 'T' trench of site 41B are:

horizon	*pedon 1*	*pedon 2*	*pedon 3*
A	0-5 cm	0-6 cm	0-8 cm
A2	5-34 cm	6-47 cm	8-112 cm
Ak	34-50 cm	(missing)	(missing)
Bkm	50-110 cm	47-107 cm	(missing)
2ABkb	110-180 cm	(missing)	112-180 cm

The 2ABkb horizon is interpreted as the uppermost part of a buried soil because it has been destratified and deimbricated, presumable by badgers living on the surface when it was subaerially exposed, though other vertebrates may have also contributed. After the overlying gravelly alluvium was deposited as parent material for the modern soil, more recent generations of badgers destratified it, and this destratification is expressed in the modern A, A2, and ABk horizons. (See Table 18 for chemical and particle size data.)

SEDIMENT-SOIL DESCRIPTION,
SITE 42, STONE SCHOOL

CLASSIFICATION: Typic Haplocalcids.
LOCATION: 500 ft (150 m) NNW of Stone School on Flat Tank-to-School Tank road (SE ¼, SW ¼, SE ¼, NE ¼, Sec. 21, T25S, R9E, Desert SE quad).
LANDFORM: Alluvial fan; A2 mapping unit.
PARENT MATERIAL: Gravelly alluvium derived from limestone.
SLOPE: 1-2%.
ELEVATION: ~4,505 ft (1,373 m).
SURFACE CONDITION: Abundant badger and gopher mounds and burrows.
VEGETATION: Desert scrub, creosote bush dominant.
SAMPLED BY: D. L. Johnson and D. N. Johnson, 6/2/96.
DESCRIBED BY: D. L. Johnson and D. N. Johnson, 6/2/96.
EXPOSURE: Backhoe 'T' trench.

Horizon	Depth (cm)	Description
A	0-5	Dark brown (10YR 4/3m, 6/3d) gravelly very fine sandy loam; strong, medium platy structures (recent surface wash stratifications intermittently preserved); slightly sticky when wet, very friable when dry; strongly effervescent with dilute HC1; common and many very fine roots; many very fine, medium and coarse pores; abrupt smooth boundary.
Ak1 (AB)	5-36	Dark brown (10YR 4/3m, 6/3d) gravelly very fine sandy loam; weak to moderate, medium vesicular structures (biopores, some possibly chrysalis capsules), destratified; slightly sticky when wet, slightly hard when dry; strongly effervescent with dilute HC1; occasional rodent/rabbit-like fecal pellets; many fine and coarse pores; few very fine and several coarse roots; gradual wavy boundary.
Ak2 (B W K1)	36-85	Dark brown (10YR 4/3.5m, 6/3d) gravelly very fine sandy loam; destratified, moderate medium subangular blocky grading to very weakly prismatic structures; slightly sticky when wet, friable to slightly hard when dry; occasional partly nodular vertical biogenic caliche structures, matrix strongly effervescent with dilute HC1; occasional rodent/rabbit-like fecal pellets; very few very fine and few medium and coarse roots; common very fine pores; gradual diffuse boundary.
ABk±m (B W K2)	85-114	Dark brown (10YR 4/3.5m, 6/3.5d) very gravelly very fine sandy loam; destratified, strong medium subangular blocky structures; slightly sticky when wet, friable to very hard when dry; strongly carbonate-cemented in places, but weakly or noncemented in others, and strongly effervescent in dilute HC1; very few very fine and occasional medium and coarse roots; common very fine and occasional medium and coarse pores; abrupt wavy boundary.
Bk	114-140	Dark brown (10YR 4/3m, 6/3.5d) very gravelly fine sandy loam (gravels stratified, some imbricated); structure less; slightly sticky when wet; some clasts wholly caliche-coated, others coated only on undersides, matrix strongly effervescent with dilute HC1; very few, very fine roots; occasional medium and coarse roots; very common very large interclast pores; clear smooth boundary to stratified and imbricated fan gravels.
CBk (C)	140-250+	Stratified and imbricated fan gravels of limestone, some caliche-coated on undersides and some with caliche pendants, some uncoated and without pendants.

Remarks: The A horizon is only 5 cm thick in this pedon but varies to ±15 cm in others. The surface of the polypedon has sporadic though fairly fresh gopher mounds, plus many new and old badger burrows whose back dirt piles contain many caliche-coated clasts up to 20-28 cm long, though most are much smaller. Other than the stratified (platy) A horizon, which apparently forms frequently via episodic eolian and sheet wash depositions—the subjacent sediments are destratified down to the Bk horizon in all pedons exposed in the backhoe pit. These stream gravels are now randomly

oriented (destratified, deimbricated) and are floating in finer matrix. This biomantle is produced by badgers, gophers, and other rodents. The upper biomantle (5-36 cm) has abundant cicada-sized and smaller, capsule-like krotovinas that impart a vesicular-like character to the upper profile. The profile schematic of Figure 98 captures the essential morphology of this pedon.

Clusters of subfossil rodent/rabbit-like fecal pellets are present in the Ak1 and Ak2 horizons, and in the latter horizon light-colored, calcareous, partly nodular vertical structures are present that were probably originally caliche-cemented cicada burrow infillings. Vesicular structures of the Ak1 horizon festoon downward into this horizon.

The interface between the biomantle and subjacent stratified gravels (i.e., between the ABk[$\pm$m] and Bk horizons) is wavy and varies in depth within the backhoe pit from 86 to 145 cm based on 11 thickness measurements of 86, 89, 99, 107, 112, 114, 130, 130, 142, 142, and 145 cm. Some clasts within the biomantle have very little adhering caliche but others are coated all around. Clasts with caliche pendants, which originally formed on their undersides, are tipped at all angles within the biomantle. (Note: the horizon notation $\pm$m, as in ABk[$\pm$m], means that the cemented ABkm horizon is commonly interrupted via bioturbation.)

In the Bk horizon certain areas contain clasts that are completely coated with caliche, whereas other zones contain clasts coated only on their undersides. Gravels below the Bk horizon are either coated or uncoated with caliche; if coated, it occurs only on their undersides.

To gain a measure of the density of badger burrowing in the area, and the sizes of the clasts they can move, all relatively old and new badger burrows and their associated mounds[3] were systematically counted, flagged, and numbered outward from the backhoe pit until 100 were counted. The burrows covered an area 159 x 83 m, or 13,197 m^2. The long axis of the largest stone from each of the 100 mounds was then measured, with values that ranged from 4 cm (1.6 in) on mound no. 11 to 29.2 cm (11.5 in) on mound no. 33, with an average of 9.3 cm (see Table 16 for these data). The weight of the largest stone observed, whose long axis measured 29.2 cm from mound no. 33, weighed 5.5 kg (12.1 lbs). (See Table 15 for chemical and particle size data.)

[3] Badger burrows and mounds ranged widely in character, from fresh ones with preserved badger claw marks on burrow entrances to those where burrows are almost completely infilled, with associated mounds flattened by erosion and wasting. In extreme cases of the latter, only a patch or scatter of caliche-incrusted gravels remain as evidence for former burrowing.

SEDIMENT-SOIL DESCRIPTION,
SITE 44, LAKE TANK PLAYA

CLASSIFICATION: Fine Typic Haplargids.
LOCATION: Lake Tank Playa is about 5 miles (8 km) SE of Davis Dome (SE ¼, NE ¼, NW ¼, Sec. 23, T26S, R8E, Desert SE quad).
LANDFORM: Playa in down-dropped tectonic depression.
PARENT MATERIAL: Calcareous playa silts and clays.
SLOPE: 0%.
ELEVATION: 4,088 ft (1,246 m).
SURFACE CHARACTER: Little disturbance evident, no cracks or bioturbation.
VEGETATION: Sparse grasses, herbs.
SAMPLED BY: D. L. Johnson, D. N. Johnson, and S. A. Hall, 6/6/96.
DESCRIBED BY: D. L. Johnson and D. N. Johnson, 6/6/96.
EXPOSURE: Backhoe 'T' trench.

Horizon	Depth (cm)	Description
A	0-24	Brown (10YR 4/2.5m, 6/2d) clay loam; weak medium platy structures; nonsticky when wet, slightly hard to hard when dry; strongly effervescent with dilute HC1; many fine medium roots; many fine and medium pores along ped interfaces; clear wavy boundary.
B	24-57	Dark brown (10YR 3/3m, 5.5/2d) clay; weak medium and coarse prismatic grading to moderate medium and coarse subangular blocky structures; hard when dry; strongly effervescent with dilute HC1; many medium roots; many fine and medium pores along ped interfaces; smooth wavy boundary.
C	57-200+	Brown (10YR 4/3m, 6/3d) clay; massive to medium and coarse angular blocky structures; sticky and very plastic when wet, very hard when dry; very few small carbonate blebs throughout; very few fine and medium roots; few fine pores.

Remarks: Lake Tank Playa is the upland base level to which several local alluvial fans and intermittent streams in this limestone setting drain. Professor Stephen A. Hall, University of Texas, Austin, palynologist, sampled this pit for pollen and found abundant well-preserved pollen. The samples were processed by washing about 100 grams of sediment in HC1 and HF, with heavy liquid separation in zinc chloride (spec. Gr. 2.0). The floatant was then washed in 2% NaOH, the same alkaline solution that radiocarbon samples are routinely washed in. Then the organic residue was oven-dried (500°C) until dry. The organic matter recovered from each 100-gram sample was about 0.8 and 0.5 grams (estimated). Two of these extracted pollen samples, from depths of 100-110 cm and 180-190 cm, were AMS (accelerator) dated and, respectively, gave corrected ages of 2,730±60 and 5,280±60 (see Table 1).

In light of these observation and data, the Lake Tank Playa sediments and site situation strongly indicate: (1) that no evidence of mixing (argilliturbation, bioturbation, etc.) Or other contamination problems exist here; (2) that the Holocene and lat Pleistocene (at least) vegetation and human-prehuman environment of this part of the southeastern Tularosa Basin and Hueco Mountains can be generally reconstructed at high levels of resolution; (3) that such a reconstruction can also be dated at high levels of resolution; and (4) that such a reconstruction would be independent (and augment) reconstructions based on pack rat middens recently done in the Hueco Mountains. (See Table 13 for chemical and particle size data.)

SEDIMENT-SOIL DESCRIPTION, SITE 46, PLUTON PIT

CLASSIFICATION: Sandy, siliceous, thermic, Typic Torripsamments.
LOCATION: About 5 m north of dirt road at summit of low saddle/divide between Lake Tank Playa on the northeast and Meyer Rifle Range on the southwest, immediately north of a mid-Tertiary igneous intrusion (GPS, 32° 22' 97' N lat., 106°, 23 23 W long.). 1.75 mi southwest of Lake Tank Playa (Centerpoint of SE ¼, NE ¼, SW ¼, Sec. 27, T26S, R8E, Desert SE quad).
LANDFORM: At terminal toeslope (~5 m north of the joining point) between two coalescing alluvial fans.
PARENT MATERIAL: Gravelly alluvium, derived from limestone hill.
SLOPE: ~2%.
ELEVATION: ~4,130 ft (1,259 m).
SURFACE CONDITION: Abundant badger, gopher, ant, and other insect mounds and burrows.
VEGETATION: Desert scrub, creosote dominant, a few mesquite.
SAMPLED BY: D. L. Johnson and D. N. Johnson, 7/26/96.
DESCRIBED BY: D. L. Johnson and D. N. Johnson, 7/26/96.
EXPOSURE: Backhoe 'T' trench.

Horizon	Depth (cm)	Description
A1 (C1)	0-12	Dark brown and brown (7.5YR 4/4m, 6/4d) fine sand; moderate medium platy structures (recent surface wash stratifications); nonsticky when wet, loose to very friable when dry; strongly effervescent with dilute HC1; common fine roots and pores; abrupt smooth boundary.
A2 (A)	12-86	Dark brown and brown (7.5YR 4/4m, 6/4d) gravelly (ls) fine sand; destratified, massive structure; nonsticky when wet, very friable when dry; strongly effervescent with dilute HC1; occasional small (~8 mm) fecal pellets; common fine and few medium roots and pores; clear smooth boundary.
A3 (C3)	86-119	Brown (7.5YR 5/4m, 6/4d) very gravelly (ls) loamy fine sand; destratified, massive structure; nonsticky when wet, very friable when dry; matrix violently effervescent with dilute HC1; few fine and medium roots and pores; abrupt wavy boundary.
Bkm	119-130	Brown and light brown (7.5YR 5.5/4m, 7/4d) very gravelly (ls) fine sandy loam; moderate to strong coarse platy-laminar structures; nonsticky when wet, hard when dry; strongly caliche-cemented, and violently effervescent in dilute HC1; rodent-sized (~6 cm dia.) krotovina extending downward into Bk2 horizon; few fine roots and many coarse interlaminar pores; clear wavy boundary.
Bk	130-180+	Light brown (7.5YR 6/4m, 7/3d) very gravelly (ls) fine sandy loam (gravels stratified); structure less; nonsticky when wet, hard when dry; gravels only weakly cemented by caliche, matrix violently effervescent with dilute HC1; very few fine and medium roots and common medium and large interclast pores; rodent-sized krotovina present.

Remarks: Two pedons were sampled in this pit, one (this description) sampled to the pit floor at 180 cm, and the other sampled to the top of the petrocalcic caliche (Bkm horizon) at 119 cm.

The gravels in the A2 horizon are mainly less than 6 cm in diameter and most of these are less than 3 cm, though a few clasts range up to 8 cm. The A2 gravels are also mainly randomly oriented, though a few tend toward the horizontal with respect to their long axes; many gravels have caliche coatings, though some have limited or no coatings. About 10% are black, chert-like clasts, which is the case all around the limestone hill on the north from which these gravels have derived.

Gravels in the A3 horizon are largely destratified and range up to 14 cm in long axis diameter, though most are less than 8 cm, and most of the latter less than 3 cm. Most gravels in the A3 horizon and throughout the profile are limestone with caliche coatings, but some black chert-like gravels present in this horizon are also caliche-coated.

Gravels in the Bkm horizon are of generally mixed sizes and more or less horizontally oriented (stratified) cemented by laminar (stage 3-4) caliche. This horizon is also strongly bioturbated by insects, with vertical, cicada-like infilled biochannels very common.

Gravels in the Bk horizon are also of generally mixed sizes and more or less stratified, though unlike the Bkm horizon this horizon is only weakly cemented by caliche.

For what it is worth, many bees and wasps had burrowed laterally into the vertical faces of the pit walls at the time the section was described. The burrowing apparently began after the pit was backhoed on May 16, 1996, and the insects were active when the pit was described on July 26, 1996. Also what it is worth, runoff from heavy rains between May 16 and July 26 entered the pit and left a debris strandline on the walls 40 cm from the bottom.

The more or less destratified biomantle, from the surface to the top of the Bk1m horizon, is variable in depth, ranging from 101 to 122 cm as determined by measurements of 101, 104, 111, 116, 117, 118, 119, 120, 121, and 122 cm from 10 pedons in site 46 'T' trench. Gravels in the Bk1m and Bk2 horizons are more or less stratified, though some destratification has occurred.

The comparative horizons thicknesses of this pedon (pedon 1) and one other pedon (pedon 2) measured in the 'T' trench of site 46 are:

horizon	*pedon 1*	*pedon 2*
A1	0-12 cm	0-14 cm
A2	12-86 cm	14-99 cm
A3	86-119 cm	99-120 cm
Bk1m	119-130 cm	120-135 cm
Bk2	130-190+ cm	135-190+ cm

(See Table 14 for chemical and particle size data.)

ABBREVIATED SEDIMENT-SOIL DESCRIPTION,
SITE 47, MEYER RANGE ROAD DEPRESSION

CLASSIFICATION: Petropedic calciargids.
LOCATION: In Meyer Range Road Depression, ~160 ft (50 m) south of Meyer Range Road, about 3.25 miles (5.2 km) west of juncture with arcuate road at Meyer Small Arms Range (SW ¼, NE ¼, SE ¼, Sec. 23, T26S, R7E, Desert SW quad).
LANDFORM: Depression in the La Mesa surface (Camp Rice fluvial facies).
PARENT MATERIAL: Sandy Camp Rice (CR) gravels over probable CR lacustrine or backswamp sediments.
SLOPE: <1%.
ELEVATION: ~4,056 ft (1,236 m).
SURFACE CHARACTER: Occasional small, polished, rounded fluvial pebbles on surface, with some evidence of gopher and badger activity.
VEGETATION: Desert scrub, yucca.
SAMPLED BY: D. L. Johnson and D. N. Johnson, 6/6/96.
DESCRIBED BY: D. L. Johnson and D. N. Johnson, 6/6/96.
EXPOSURE: Backhoe 'T' trench.

Horizon	Depth (cm)	Description
A	0-40	Strong brown (7.5YR 4/6m, 5/4d) slightly gravelly loamy sand (gravels are from Camp Rice Formation); krotovina present; clear smooth boundary.
Bk	40-112	Strong brown (7.5YR 4/6m, 5/4d) slightly gravelly sandy loam; krotovina present; common caliche blebs, matrix strongly effervescent with dilute HC1; abrupt smooth boundary.
2Btkb	112-175	Strong brown (7.5YR 4/6m, 5/4d) slightly gravelly clay loam; strong, medium coarse prismatic structures; caliche precipitated along prisms, matrix strongly effervescent with dilute HC1; abrupt smooth boundary.
3Ab	175-220	Strong brown (7.5YR 4/6m, 5/4d) slightly gravelly loamy sand; abrupt smooth boundary.
3Btkb	220-270+	Calichefied, gravel-free, probable lake sediments that exhibit strong coarse prismatic structures, breaking to strong coarse angular blocky structures; caliche masses are precipitated along vertical prismatic structures, as are thin manganese filaments and thick continuous clay films.

Remarks: The stratigraphy here appears to be Camp Rice gravelly sands above Camp Rice lake clays, all of which have been pedogenicized to varying degrees. Krotovina occur from the surface to 112 cm depth, with animal burrows and brachiated root systems abundant.

SEDIMENT-SOIL DESCRIPTION,
SITE 50, RANGE CONTROL DEPRESSION

CLASSIFICATION: Typic Haplocarrbids.
LOCATION: ~2.5 miles (4 km) NNW of McGregor Range Camp Missile Gate entrance (SE ¼, NE ¼, SW ¼, Sec 23, T25S, R7E, Desert SW quad).
LANDFORM: Dunal depression on La Mesa surface; DS/CR/A1/P1 mapping unit.
PARENT MATERIAL: Eolian sand.
SLOPE: <1%.
ELEVATION: 4,088 ft (1,246 m).
SURFACE CHARACTER: A few rodent mounds.
VEGETATION: Desert scrub, mainly mesquite, creosote bush.
SAMPLED BY: D. L. Johnson and D. N. Johnson, 6/12/96.
DESCRIBED BY: D. L. Johnson and D. N. Johnson, 6/12/96.
EXPOSURE: Backhoe 'T' trench.

Horizon	Depth (cm)	Description
A	0-6	Yellowish red (5YR 3/3.5m, 4/6d) sand; moderate medium platy structures; nonsticky when wet, very friable when dry; slightly effervescent with dilute HC1; occasional small, water-polished (Camp Rice) pebbles; common fine roots; many medium pores; abrupt wavy boundary.
Bw1	6-80	Dark reddish brown (5YR 3/4m, 4/6d) loamy sand; moderate extremely coarse prismatic structures; nonsticky when wet, friable to slightly hard when dry; slightly effervescent with dilute HC1; occasional small, water-polished (Camp Rice) pebbles; few fine roots; common fine and medium pores; smooth gradual boundary.
Bw2	80-210	Yellowish red to reddish brown (5YR 4/5m, 4.5/6d) slightly gravelly sand; massive structure; nonsticky when wet, very friable when dry; generally slightly to moderately effervescent (strong in places) with dilute HC1; occasional small, water-polished (Camp Rice) pebbles; common small krotovina; very few very fine roots; common very fine intergrain (interstitial) pores; abrupt wavy boundary.
Bk (Bkb)	210-246	Yellowish red to reddish brown (5YR 4.5/6m, 6/4d) loamy sand; massive structure; nonsticky when wet, friable to slightly hard when dry; light powdery caliche, strongly effervescent with dilute HC1; occasional small, water-polished (Camp Rice?) pebbles; very few very fine roots; few fine pores; abrupt wavy boundary.
Bkm (Bkmb)	246-310+	Whitish, dense laminar caliche (petrocalcic horizon); violently effervescent with dilute HC1.

Remarks: This soil formed in an undulating sheet sand within which, and on the surface of which, water-polished Camp Rice gravels are occasionally met, presumably brought up and dispersed into the sand sheet by bioturbation. Several termite sheaths formed vertically on the wall of this pit between the time it was dug in mid-May and when it was described in mid-June.

APPENDIX E

LITERATURE REVIEW

INTRODUCTION

This section lists the literature consulted for this report by topical theme. Where a study is multithematic, the topic that appears hierarchically most important and/or stressed is included under that heading. In the sections which follow, some of this literature is evaluated in more detail as it relates to the discussions at hand.

ARCHEOLOGICAL STUDIES

Studies that relate directly to the McGregor Range or immediately nearby include those by Anschuetz et al. (1990), Beckes (1977a, 1977b), Beckes and Dibble (1977a, 1977b), Beckes et al. (1977), Broilo (1973), Burgett (1994), Carmichael (1986, 1990), Chrisman et al. (1996), Church et al. (1994), Doleman and Swift (1991), Doleman et al. (n.d.), Dulaney and Pigott (1977), Hard (1980, 1983), Hedrick (1967), Leach et al. (1997), Mauldin (1993, 1995), Mauldin et al. (n.d.), Mbutu and Peter (1994), Miller (1996), Peter and Mbutu (1992), Pigott and Dulaney (1977), Russell (1968), Scott (1977), Skelton (1981), Skelton and Dibble (1981), Skelton et al. (1981), Smiley (1981), Whalen (1977, 1978), Wilson (1984), and Zeidler et al. (1996). Those that deal with more regional perspectives include Eidenbach (1983), Hall (1973), LeBlanc and Whalen (1980, 1993), and Whalen (1981).

ECOLOGICAL STUDIES

Studies that directly relate to the McGregor Range or immediately nearby include those by Cummings (1993), Gish (1993), Kenmotsu (1977), Satterwhite and Ehlen (1980), and Wyatt (1976). Those that deal with more regional perspectives include Ammon (1958), Brown (1984), Bryan (1929), Buffington and Herbel (1965), Campbell (1929), Chew (1979), Gibbens and Beck (1987, 1988), Gibbens et al. (1983, 1986, 1992, 1993), Gile et al. (1995, n.d.), Graham Gadzia and Ludwig (1983), Harris (1977), Hennessy et al. (1983a, 1983b, 1985), Lee (1986), Schmidt (1979), Whitford (1965), Whitford et al. (1975), Wierenga et al. (1987), and York and Dick-Peddie (1969).

GEOLOGICAL STUDIES

Studies that relate directly to the McGregor Range or immediately nearby include those by Bachman and Hayes (1958, 1959), Beane et al. (1975), Blair et al. (1990), Cave (1959), Clark (1959), Darton (1928), Foster (1959, 1978), Gustavson (1991), Harder (1982), Hardie (1958), Hawley (1975b, 1993), Hunt (1977, 1978), Jordan (1975), Kalidas (1995), King et al. (1945), King and Harder (1982), Lanka (1995), LOCSWA (1993), McFaul and Doering (1992), Mack et al. (1996), McKee (1965), North (1982), Pigott (1977), Pray (1954a, 1954b, 1954c, 1959a, 1959b, 1959c, 1959d, 1961, 1977a, 1977b), Reynolds and Craddock (1959), Sandeen (1954), Schmidt and Craddock (1964), Seager (1961, 1980), Seager et al. (1987), and Strain (1969). Those that deal with more regional perspectives include Allen (1959), Anonymous (1954), Bachman and Mehnert (1978), Bachman et al. (1954), Barnes (1983), Black (1973, 1975), Chapin and Seager (1975), Condie and Budding (1979), Cooley (1958), Decker et al. (1975), Dunn and Alcorn (1959), Evans (1958), Glover (1975), Gustavson et al. (1995), Harbour (1972), Hawley (1969, 1975a), Hawley et al. (1969), Jicha (1954), Kottlowski (1958b, 1959, 1975), Kottlowski et al. (1969), Lovejoy (1975), Machette (1987), Mack and Seager (1995), Metcalf (1969), Pray (1954b, 1954d, 1958), Richmond (1964), Ruhe (1962), Seager (1973, 1975, 1981, 1995), Seager et al. (1984), Stipp (1954), Strain (1965, 1980), and Stuart and Willingham (1984).

GEOMORPHOLOGY AND SOILS

Studies that relate directly to the McGregor Range or to nearby areas include those by Buck (1993, 1996), Davis (1976), Davis and Nials (1988), Derr (1981), Doleman and Swift (1991), Fitzsimmons (1955), Gile (1966, 1975, 1977, 1987, 1994a, 1995), Gile et al. (1981), Kipp (1993), Monger (1993a, 1993b, 1993c, 1993d, 1993e), Monger et al. (1993), Nash (1993), and Pigott (1977, 1978, 1981). Those that deal with more regional perspectives include Aristarain (1970, 1971), Buol (1965), Bureau of Reclamation (1961), Christy (1959), Davis and Nials (1988), Gile (1994b, 1995), Hennessey et al. (1986), Morrison (1969), Mott (1959), Ruhe (1967), and Soil Systems (1978).

HISTORICAL STUDIES

Historical studies of the McGregor Range and or nearby areas have been executed by Faunce (n.d.), Freeman (1977, 1981), Fulton (1954), Hawthorne (1994), Kelley (1975), McBride (1958), and Sanders (1982).

HYDROLOGY AND WATER RESOURCES

Water resource studies in the southern Tularosa and Hueco basins and areas surrounding McGregor Range have been executed by Allmendinger and Titus (1973), Anonymous (1956), Burns and Dart (1988), Cliett (1969), Conover et al. (1955), Doty and Cooper (1970), Garza and McLean (1977), Herrick and Davis (1965), Hood (1959), Kelley (1973), Kelley and Hearnes (1976), Knowles and Kennedy (1958), McLean (1970a, 1970b, 1975), Meinzer and Hare (1915), Mourant (1959), Orr and White (1985), Orr and Myers (1986), Powell and Staley (1928), Stone (1988), Stone et al. (1979), Stucky and Arnwine (1971), Techrad (1980), Wilson and Myers (1981), and Zohdy et al. (1969).

QUATERNARY ENVIRONMENTAL STUDIES

Such studies in the southern Tularosa-Hueco basins and surrounding areas have been executed by Allen (1991), Buck (1996), Buck and Mack (1995), Eliàs (1987), Hawley (1993), Herrick (1904), Khresat (1993), Kottlowski (1958a), Mack et al. (1991, 1994), Reeves (1969), Van Devender (1990), and Van Devender et al. (1984, 1987).